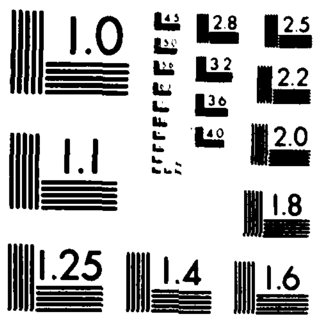
AD-A136 831 OPERATIONAL AND FUNCTIONAL DESCRIPTION OF AERA 101(U) 1/2
FEDERAL AVIATION ADMINISTRATION WASHINGTON DC SYSTEMS
ENGINEERING SERVICE W J SWEDISH ET AL. 31 SEP 83
UNCLASSIFIED DOT/FAA/ES-83/9 F/G 17/7 NL


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

(11)

U.S. Department of Transportation
Federal Aviation Administration
Office of Systems Engineering Management
Washington D.C. 20591

Operational and Functional Description of AERA 1.01

AD-A136831

September 1983
Report No. DOT/FAA/ES-83/9

014

Technical Report Documentation Page

1. Report No. DOT/FAA/ES-83/9	2. Government Accession No. AD-A136 831	3. Recipient's Catalog No.
4. Title and Subtitle Operational and Functional Description of AERA 1.01		5. Report Date September 31, 1983
		6. Performing Organization Code AES-320
7. Author(s) W.J. Swedish, B.C. Simmerman, A.W. Lipps, J.G. Steinbacher		8. Performing Organization Report No. FAA-ES-83-9
9. Performing Organization Name and Address Systems Engineering Service, Department of Transportation, Federal Aviation Administration, 800 Independence Ave., S.W., Washington, D.C. 20591		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Same as #9 above.		14. Sponsoring Agency Code AES
15. Supplementary Notes		

16. Abstract

The AERA 1.01 functions, to be implemented as part of the Advanced Automation System for en route air traffic control, consist of:

- Trajectory Estimation;
- Flight Plan Conflict Probe;
- Airspace Probe; and
- Sector Workload Probe.

This document presents a high-level operational and functional description of these four advanced automation functions. The operational description discusses the effect of the advanced automation functions on the controller: what information must be provided to the functions, what information is received from the function, which controller receives that information, and what the controller's response should be. The effect of these functions on the structure of the controller's job, such as training and staffing requirements, is also discussed. The functional description presents the logical organization of the advanced automation functions, including the role of each function and the interfaces between functions.

17. Key Words Automation, Air Traffic Control, Automated Decision Making, En Route Traffic Control, Artificial Intelligence, Advanced Automation System	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

EXECUTIVE SUMMARY

INTRODUCTION

The "National Airspace System Plan" for the development of the nation's air traffic control system over the next 20 years was published by the Federal Aviation Administration (FAA) in December 1981, and revised in April 1983.

As part of this plan, the computers presently used for air traffic control (ATC) will be replaced by modern "host" computers which can support the current NAS Stage A En Route software with minimal changes. Also, new controller workstations known as Sector Suites will be introduced after the host computers have been installed.

The next stage of automation development is referred to as the Advanced Automation System, or AAS. The AAS will provide still more computing speed and capacity, by either expanding or replacing the host computers. In addition, new software will be provided for the AAS, including several new functions which are referred to as AERA. The AERA functions will provide additional planning and control tools to the air traffic controller, in order to improve productivity and enhance safety while benefitting the airspace users.

Evolution of the AERA Functions

Implementation of the AERA functions was described in a previous MITRE document, "Evolution of Advanced ATC Automation Functions," as a series of automation stages. By this plan, AERA 1 will introduce the new software tools, providing planning aids to the controller to allow improved user services. AERA 2 will provide computer-aided decision-making tools for the controller, enhancing productivity and efficiency. In AERA 3, the computer is to be capable of predicting control problems such as aircraft conflicts, generating resolutions for those problems, and transmitting ATC clearances to the aircraft involved, with monitoring and only occasional intervention from the controller.

AERA 1 is composed of two separate packages, referred to as AERA 1.01 and AERA 1.02. AERA 1.01, the initial package of advanced automation features, is to be implemented as part of the initial AAS. AERA 1.01 will consist of four functions:

- Trajectory Estimation will calculate the flight path of the aircraft in three dimensions (x, y, z) and time (t), based on information from flight plans and other sources.

- Flight Plan Conflict Probe will compare aircraft trajectories in order to test for conflicts between aircraft, situations in which aircraft separation minima are predicted to be violated.

- Airspace Probe will use the aircraft trajectory to test for conflicts with specific static adapted airspace volumes (special use areas and terrain).

- Sector Workload Probe will display various workload-related measures to supervisory personnel, to assist in determining sector manning levels and/or resectorizing as necessary to balance workload.

Later AERA packages will add enhancements to these functions and integrate them more closely with the other ATC functions.

Impacts of AERA

A goal of AERA 1.01 is to improve the ability of the ATC system to accommodate user-preferred altitudes and routes, including direct and off-airway routes. Flight Plan Conflict Probe and Airspace Probe are expected to reduce the workload involved with monitoring such flights and coordinating across sector boundaries.

These functions are also intended to help the controller be aware of a future separation violation earlier than in the current ATC system. There should therefore be more time in AERA 1.01 to develop an efficient and effective resolution. The desired result is a smoother flow of traffic and a more even pace for the controller.

Although these benefits are expected from AERA 1.01, the net impact on ATC operations will probably not be large. Most of the benefits of advanced automation will not be realized until the later stages, after the AERA functions have been further developed and more fully integrated with the rest of the ATC system. The primary benefit of AERA 1.01 will be the introduction of the initial AERA functions, providing the necessary first step towards the greater benefits expected from full AERA implementation.

Purpose

The purpose of this document is to describe the AERA 1.01 functions in greater detail than in previous AERA documentation. It is intended that this description of the AERA 1.01 functions will stimulate further discussion and consideration regarding the operational use of the functions, and that a process of refinement and revision will ensue which will ensure that advanced automation

contributes to the development of a more efficient and effective ATC system. To help achieve this objective, the presentation includes, in addition to a discussion of the interrelationships of the AERA functions among themselves and with pre-existing automation functions, discussions of the effect of new automation tools on the way controllers provide ATC services. Considerations of the impact of AERA 1.01 on controller directives, work practices and procedures, and staffing and training policies are also included.

This document reflects the present state of the AERA design. Issues relating to the operational use of AERA functions remain unresolved. In some cases, resolution of these issues depends upon details of the AAS design, most importantly with respect to the AAS Man-Machine Interface, which have not yet been established and which are beyond the scope of the current AERA design activities. Resolution of other issues depends upon achieving a better understanding of the impact of AERA on ATC operations. Extensive testing at MITRE and the FAA Technical Center is planned to assess the operational suitability of AERA functions. It can be expected that the definition of AERA capabilities will undergo continued refinement as a result of these tests.

DESCRIPTION OF THE ATC FUNCTIONS IN THE AAS

AERA 1.01 will consist of Trajectory Estimation, Flight Plan Conflict Probe, Airspace Probe and Sector Workload Probe. These AERA 1.01 functions will be added to the set of other ATC functions in the AAS, a majority of which will be carried forward from NAS Stage A. The basic functional capabilities of the NAS En Route Stage A system consist of the Surveillance Data Processing capability, the Flight Plan Processing capability, and some additional functions including system support, backup and monitoring features. These primary ATC functions of today will remain essentially unchanged in the AAS.

The Surveillance Data Processing capability includes processing the raw data input, displaying the surveillance data to the controller, tracking the radar targets, and providing separation assurance functions based on the tracked targets. The Flight Plan Processing capability accepts, checks, processes, and distributes flight plan data for individual flights. The flight data will be electronically displayed to the controller as part of the new Sector Suites.

The primary functions of the present ATC system will be augmented by several enhancements to the NAS En Route Stage A system prior to the AAS and AERA 1.01. These include En Route Metering II (ERM II), Conflict Resolution Advisories (CRA), and an IFR/VFR Conflict Alert function, and may include an interface with the data link feature of the Mode S sensor system.

ADVANCED AUTOMATION AND THE COMPUTER--FUNCTIONAL DESCRIPTION

The following paragraphs describe the internal organization of the four AERA 1.01 functions, including discussion of the interfaces of the new functional elements with the other ATC functions (referred to here as the "external" interfaces) as well as the internal interfaces between the elements.

The Trajectory Estimation (TJE) component is responsible for the construction of the four-dimensional (x, y, z, t) aircraft trajectories. It may be called upon to create a trajectory for two different reasons: because a new plan was received or because an existing plan needs to be modified, due to a flight plan amendment or automatic updating.

The TJE component includes two separate subfunctions, Nominal Plan Builder and Trajectory Construction. Nominal Plan Builder creates a list of "Planned Actions" which reflect pilot intents implied by the flight plan and by ATC standard operating procedures implicit in transitioning the Planning Region. An example of such a Planned Action would be the change in altitude for a descent to the destination airport.

Trajectory Construction then merges the converted flight plan with the list of Planned Actions, taking into account weather factors and aircraft performance data. The modeled trajectory is composed of a sequential list of points representing a four-dimensional estimate of aircraft position at all locations along the cleared route of flight within the Planning Region. The completed aircraft trajectory is stored in the system data base where it will be subsequently accessed by the components requiring the trajectory as input.

Flight Plan Conflict Probe (FPCP) uses the estimated trajectories of controlled aircraft to test for future violations of separation criteria between a specified subject aircraft and other (object) aircraft trajectories in the ACF Planning Region. It is to be activated to probe for conflicts for an aircraft when the trajectory for that aircraft is first created, and whenever the trajectory is modified.

The Airspace Probe (AP) component uses the estimated trajectory of a specified subject aircraft to predict future entry of that aircraft into particular types of active special use airspace or into close proximity with terrain or other violations of specified minimum altitudes. The Airspace Probe is to be performed automatically in conjunction with Flight Plan Conflict Probe; however, it may also be executed independently of FPCP following an activation/deactivation

of a designated airspace. The designated airspaces (Restricted Areas, Military Operation Areas, Warning Areas, MSAW polygons, etc.) are to be adapted with an altitude floor and ceiling, specific geographic boundaries, the times of activation/deactivation and other identifying information.

Sector Workload Probe (SWP) evaluates the expected (future) workload of a sector or sectors in order to provide supervisory personnel with advance warning of periods in which a significant change to workload is expected. Sector Workload Probe will execute upon receipt of an immediate supervisor request for data, or at regular intervals. SWP calculates the following types of information for each requested time interval based on trajectory information: a weighted sum of planned ATC actions, the number of aircraft, the number of projected aircraft encounters, and a traffic density measure. In addition, a single aggregated measure will also be available.

External Interfaces

The advanced automation functions will acquire input data from existing ATC system functions and return function output to the system after processing.

The AERA 1.01 functions receive the following types of input data from other automated functions and system data bases: flight plan data, aircraft performance data, weather information, and special use airspace definitions. The first three types of data are inputs to the Trajectory Estimation function. The special use airspace definitions are used by Airspace Probe in the detection of airspace violations. In addition to the input data, TJE may receive a request for replan due to the need for resynchronization.

Information on new flights or current flights with route amendments is received from the AAS Route Conversion function in the form of a horizontal route plan which consists of a sequence of (x, y) points. TJE then uses aircraft performance data to create a trajectory based on the expected performance of a particular aircraft or class of aircraft.

The Trajectory Estimation process also makes use of weather information when constructing trajectories. This information (winds aloft and temperatures aloft) is obtained from the Central Weather Processor (CWP), which has consolidated information from National Weather Service, pilot reports, and other sources. The Trajectory Estimation process may provide feedback on wind information. Wind error accumulation information, deduced from aircraft deviation data, would be supplied to the Center Weather Service Unit (CWSU) for evaluation and possible use.

The Airspace Probe requires definition of the special use areas, including such data as identification of the areas (e.g., by name or number), a geographic description of the polygons representing the areas, activation times, and applicable altitudes.

The AERA 1.01 functions also have a number of interfaces with the controller or supervisor. The controller is responsible for updating the trajectory data base to reflect all clearances given to, and acknowledged by, aircraft under his control. Input of these messages is an extremely important interface because it keeps the projected trajectories in close correspondence with the ATC clearances as known by the pilot, which improves the accuracy with which the probe functions can detect conflicts.

The output to the controller consists of the conflict information processed by the conflict probes (Airspace Probe and Flight Plan Conflict Probe) to provide the controller with the relevant information about the aircraft involved. Additional information regarding a particular conflict situation may be available to the controller upon request, and may include a graphic display of the conflict situation.

Output to the supervisor from the Sector Workload Probe consists of the presentation of workload-related measures in the form of sector-specific reports, covering specified time intervals.

Internal Interfaces

Trajectory Estimation has no internal source of input data but it provides output to the other three AERA 1.01 functions, in the form of aircraft trajectories. Both Flight Plan Conflict Probe and Airspace Probe receive the trajectories from TJE as one of their inputs. Sector Workload Probe has three internal sources of data: the aircraft trajectories from TJE and the conflict information from Airspace Probe and Flight Plan Conflict Probe; it has no internal AERA interface for its output, but other users such as display processors may access the data.

ADVANCED AUTOMATION AND THE CONTROLLER--OPERATIONAL DESCRIPTION

One of the most important interfaces of the AERA 1.01 functions will be with the human element of the ATC system, principally the controllers and supervisors. Some of the data flows from the functions to the human element have already been mentioned. The following paragraphs will discuss how that data may be used by controllers and supervisors in performing their tasks, how the new functions will provide new control tools and the impact of those tools on the controller's and supervisor's responsibilities.

New Control Tools

For this discussion, an air traffic control tool is defined as an automated aid which is visible to the controller and which assists in the performance of control tasks. Four new tools will be introduced by AERA 1.01:

- Flight Plan Conflict Probe
- Airspace Probe
- Sector Workload Probe (for supervisors)
- Trial Plan Probe

Three of these tools are directly linked by name to three of the new functions of the AAS. The fourth tool, Trial Plan Probe, is a controller-initiated version of the Flight Plan Conflict Probe and Airspace Probe sequence. Its role is to assist the controller in testing trial plans and amendments for potential conflicts with other aircraft, special use airspace, or terrain. These tools are supported by the Trajectory Estimation function.

The following operational description is predicated on the following ground rule assumptions:

- The controller will continue to be ultimately responsible for detecting and resolving all conflicts. Where they are applicable, however, the probe functions are intended to be the principal conflict-detection tool.

- The probes produce valid results only when the aircraft are in conformance with their trajectories. When an aircraft is out-of-conformance, the controller will be expected to re-establish conformance as quickly as possible. (How the probes deal with the trajectories of out-of-conformance aircraft must still be determined.)

- The AERA 1.01 tools will not replace or displace any other automated or manual tool or function, but will augment those tools.

- Conflicts will be detected by the probes using parameters based on radar separation minima and vertical separation minima.

- The probes will introduce new displays or lists, new actions, and new procedures, and will imply new directives.

The following issues will serve as a focus for the discussion of the AERA 1.01 tools.

- How much of the controller's job is affected by the tools?

- How does the controller use the tools?

- How do the tools help the controller fulfill his responsibilities?

- What new tasks are imposed by the tools?

- How do the tools fit in with the controller's other activities?

Controller Tasks and Control Environment

The controller's job can be divided into seven functional areas or tasks, as follows:

- Monitor Traffic
- Maintain Aircraft Separation
- Formulate and Issue Clearances
- Transfer Control and Communications
- Meter Traffic
- Respond to Pilot/Controller Requests
- Issue Safety Advisories and Informational Messages

These tasks are defined in broad terms so that, taken together, they encompass the vast majority of the activities the controller performs day to day. Some of the tasks overlap. For each task, the controller's responsibilities and the applicable AERA 1.01 tools can be identified. Only a subset of the controller's tasks will be affected by the new tools.

Some tasks are more critical than others. The critical tasks must be performed continuously or without delay to insure aircraft safety, while other tasks may be postponed temporarily. The following priority scheme has been adopted in these task descriptions.

- The tasks that must be performed continuously or without delay and which are safety-related are labeled as Priority One.

- The tasks that are concerned with the expeditious flow of traffic and which are important to the maintenance of order and control in the ATC system are labeled as Priority Two. These tasks are important but are performed after aircraft safety has been assured through Priority One tasks.

- Priority Three tasks are to be performed on a workload-permitting basis only. These tasks provide assistance to the pilot, but are not directly involved in issues of safety or control.

AERA 1.01 affects mainly Priority One tasks. To the extent that control functions (Priority Two) include safety-related tasks (Priority One), they also are affected by the AERA 1.01 tools. Table 1 indicates the principal application of the AERA 1.01 tools to the seven controller task areas. The table also groups the tasks by priority.

The en route controller using the advanced automation tools will be operating within the Sector Suite work station. A number of logical displays required by the controller in the Sector Suite have b identified in the AAS Specification. These logical disp s describe the functional grouping of information presented to controller as a single entity. The displays thus far specif include:

- Situation Display--geographic and track data, as in toda PVD.

- Flight Data Display--flight information for aircraft of interest to the controller (similar to today's flight strips).

- Metering Advisory List Display--information and advisory data calculated by the en route metering function.

- Alert and Resolution Display--information on alert or warning conditions detected by the system or input by the controller and that information necessary for resolving the alert condition.

- Message Composition and Response Display--made up of two displays: (1) a message composition display which contains a message preview area and a menu area, and (2) a response display which contains computer responses to controller-input messages or queries; similar to CRD in NAS Stage A.

The incorporation of the AERA 1.01 functions into the ATC system will generally not require new logical displays, although details of the design of the displays will be affected. However, there may be a need for an additional logical display to accommodate graphic information relating to a future event (such as a probe-detected conflict).

TABLE 1
APPLICATION OF AERA TOOLS

	CONTROLLER TASK	AERA TOOL FPCP	AP	TPP
Priority ONE	Monitor Traffic	X	X	
	Maintain Aircraft Separation	X	X	X
	Formulate and Issue Clearances			X
Priority TWO	Transfer Control and Communications			
	Meter Traffic			(X)*
	Respond to Pilot/Controller Requests			X
Priority THREE	Issue Advisories and Information			

*TPP can assist the controller in evaluating metering strategies for potential conflicts

Use of the Advanced Automation Controller Tools

The Flight Plan Conflict Probe will assist the controller in detecting situations in which separation minima between aircraft may be violated. The automated probes will be able to detect such situations further in the future than the controller typically can in today's system. Though these situations fit the current definition of "conflict" (a situation in which applicable separation minima may or will be violated), they are different from "conflicts" detected in NAS Stage A in two important ways. First, because of the longer lookahead times, the estimates of future aircraft position are more subject to variations in winds and aircraft performance, and thus there may be less certainty that a separation violation will occur if no control action is taken.

Secondly, the long lead time may reduce the need for prompt resolution. Requiring the controller to resolve all such situations promptly may therefore increase workload without significantly increasing system safety. It is useful to create a new category of "possible problem areas" to include these situations which do not require prompt resolution.

Such situations will be referred to in this document as "Advisory Conflicts." Although not required to resolve all such situations immediately, the controller may want to devote extra attention during monitoring tasks to the possible problem, and plan aircraft movements in such a way as to reduce the likelihood of a conflict developing. If, on the other hand, prompt action by the controller is deemed necessary to avoid a separation violation, this situation will be called a "Priority Conflict." These two types of situations, Advisory and Priority Conflicts, will be identified to the controller through advisory and alert messages, respectively.

When an Advisory Conflict is detected by the Flight Plan Conflict Probe, an advisory message will be sent to one or more of the involved controllers. Particularly in complex situations such as ones in which the aircraft involved are currently in different sectors and the predicted point of violation is in a third sector, the issue of who gets the advisory message is non-trivial and a subject for study.

The advisory message is primarily a notice to the controller to be aware of and monitor the situation closely because it may develop into a Priority Conflict. The controller may, at his option, take measures to resolve the situation. The advisory message contains information necessary for the controller to identify the Advisory Conflict, such as identification of aircraft involved, location of predicted violation, time of violation, and IDs of sectors with current control of the aircraft involved. Additional information

may be available to the controller via an alternate display, e.g., a graphical representation of the situation.

The alert message informs the controller of a Priority Conflict detected by the Flight Plan Conflict Probe. It identifies the conflict to the controller by presenting the same information as is included in the advisory message. Additional information may be available on an alternate display, as for Advisory Conflicts.

A control directive will be required to assign responsibility for initiating the required coordination and for resolving the conflict. In most cases it is expected that the alert message will be sent to the controller in whose sector the violation is predicted to occur, and possibly to other involved controllers. The assignment of responsibility is subject to modification and elaboration as a result of further study.

The controller's responsibility with respect to any Priority Conflict situation, whether it is detected by an automated probe or by mental monitoring activities of the controller, will be to resolve it promptly, as established by the appropriate directives.

The controller's responsibility in the AAS with respect to special use airspace will be unchanged. It is the controller's responsibility to clear non-participating aircraft via routing which will provide approved separation from the special use airspace, unless clearance of non-participating aircraft in or through the area is provided for in a Memorandum or Letter of Agreement. It is the pilot's responsibility to be aware of areas of special use airspace and, unless permission to enter an area has been granted by the using agency of the area, to structure his flight plan such that these areas are avoided.

Some airspace conflicts may be detected by Airspace Probe considerably in advance of the predicted violation (similar to Advisory Conflicts). This advance notice of possible airspace conflicts has two implications:

- Very early coordination with the pilot may be effected, to allow the pilot to resolve the problem (since he has primary responsibility for avoiding reserved airspace).

- Resolution of the problem may be deferred (because of controller workload) until the aircraft is in proximity of the sector in which the airspace conflict occurs.

If an airspace conflict is detected more than a stated (system parameter) number of minutes before the predicted violation, an Airspace Violation advisory message is sent to the controller then in control of the aircraft (or about to be in control if the aircraft has not yet entered the center). The controller's responsibility with respect to an Airspace Violation advisory message will probably be to treat the pilot notification as an additional service. If time and workload conditions permit, the controller will:

- Advise the pilot of the problem
- Approve/disapprove the pilot-suggested plan amendment (if the pilot offers an amendment)
- If assistance is requested by the pilot, suggest a plan amendment which resolves the problem

The purpose of the Airspace Violation alert message is to inform the controller that an aircraft which is currently under his control has a conflict with an area of special use airspace or with terrain. The responsibility of the controller will be to determine if the aircraft should be permitted to enter the specified airspace, and if permission is not to be given, to provide the pilot with routing around the airspace.

The Trial Plan Probe is an advanced automation tool that is intended to assist the controller in evaluating a trial plan (i.e., one being considered for implementation) in terms of whether it would resolve any previously identified conflicts and/or create new conflicts. The Trial Plan Probe is to be used in situations that do not require immediate controller intervention to avoid a separation violation. Examples of typical situations for use of the Trial Plan Probe would be in responding to a pilot request for an off-airway route segment or other changes in aircraft routing.

The Trial Plan Probe will be performed only on controller request. Trial plans will most likely be input into the computer in the same manner as current plans. The results of the probe will be presented only to the controller who initiated the probe.

If a potential conflict is detected by the probe, the controller will be presented with a message which contains information necessary to identify the potential conflict. The information contained in this message should be the same as the information presented to the controller when a real conflict is detected by the automated probes. If the Trial Plan Probe detects no potential conflicts, the controller is explicitly so informed.

The controller will be expected to use the results of the probe and his knowledge of the current situation to decide whether or not to implement the trial plan. If the controller decides to implement the trial plan, the controller will transmit an appropriate clearance to the pilot and receive an acknowledgment. The controller will then indicate to the computer that the trial plan is to be accepted as the current plan. If it is determined that the trial plan is unacceptable, the controller could reject it and repeat the evaluation process with an alternative plan.

The Sector Workload Probe is intended to aid supervisory personnel in planning and conducting sectorization (combining and decombining sectors) and positional manning. Information provided by the probe to assist the supervisor would include the following data for each sector:

- The current and anticipated number of aircraft
- The current and anticipated number of conflicts
- Some "weighted" sum of anticipated planned actions related to the number of clearance changes to be issued
- The current and anticipated density of the traffic flow

Lastly, a single aggregate measure could be provided. The information for each sector can include data for various time periods in the future up to the limit of the probe function.

It will be the responsibility of the supervisor or manager to interpret the significance of the different categories of information and determine the manner in which to use the information. By comparing the expected sector workload with the current sector workload, the supervisor can determine whether or not resectorization or manning changes are needed. Such decisions will be based upon experience and according to ATC rules and directives.

Impacts of the Advanced Automation Tools on the Controller

The new tools for the controller are intended to provide several significant improvements upon current ATC capabilities, particularly the ability of the probes to detect conflict situations sooner than the human can under a wide range of circumstances. By giving the controller more time in which to resolve the conflict, the possible resolution strategies available to the controller would increase. The use of immediate maneuvers and workload-intensive resolutions is expected to decline correspondingly. The probes will provide information on conflicts that can be presented to the controller in an

integrated, unified format, thereby reducing the amount of time required to "get the picture," and allowing the controller more time to formulate and evaluate resolutions. The probe functions may also help to reduce the amount of coordination between controllers in certain circumstances.

The probes will impose some additional requirements on the controller in order to obtain these benefits, mainly by emphasizing such good control practices as entering all flight plan amendments promptly and maintaining a close conformance between the actual route of the aircraft and its current clearance (by updating the clearance or by guiding the aircraft back into conformance). The probes operate on the flight plan information in the data base, and will be most accurate when the data base is up-to-date and representative of the current situation (i.e., when the aircraft and trajectory are in conformance).

Display/Input Considerations

With the additional emphasis to be placed on maintaining the system data base, it is essential that the controller interface be designed to facilitate entry of the required information. Similarly, the mode in which information is displayed to the controller will greatly affect the usability of the advanced automation functions.

ADVANCED AUTOMATION AND AIR TRAFFIC MANAGEMENT

In certain cases, the new capabilities of AERA 1.01 may result in procedural or managerial changes which affect the entire controller community. For instance, the advanced automation functions could have implications on staffing levels of operational personnel or on practices of positional manning of control sectors (one-person, two-person, etc.). Of particular interest is the aggregate effect on manpower and productivity.

Staffing and Manning

Staffing, in this report, means the numbers of controllers, supervisors, and other personnel designated for an air traffic control facility. Manning means the assignment of personnel to the operational positions.

The controller will continue to hold the ultimate responsibility for detecting and resolving conflicts using all available information, whether from the probe functions or otherwise. The controller will be directed to take appropriate action when notified of a probe-detected conflict situation.

Probe-related actions could therefore add to the aggregate workload. Such additional workload, even if not alleviated, does not seem to be enough to require increases in staffing levels. At most, this workload could affect criteria for manning a sector with one or two controllers.

Factors which act to alleviate the "added workload" enough to counterbalance it, or possibly reduce the aggregate workload, would be related to more efficient planning and a more effective distribution of workload among two or more sectors. The overall effect of these conditions on total sector workload cannot be determined until operational details are made clearer.

Training and Proficiency Levels

The new actions called for by the probes will require additions to documentation for initial training and proficiency maintenance training. These actions include those associated with manual inputs, the memorization and use of new terminology and concepts, and new phraseology for operations. In addition, new training will include all aspects related to new Directives. Finally, additions to on-the-job training will be required.

The impact of the AERA 1.01 functions on training will be in addition to, and should be integrated with, the changes resulting from the introduction of the AAS and the Sector Suite.

Proficiency levels in the performance of certain probe-related actions may be required to meet fairly rigid standards for uniformity and promptness of action in order to provide a data base that will ensure the validity and timeliness of conflict detection by probes.

Changes to Directives

The simultaneous incorporation of new information on the displays, new tools, new procedures, or new actions will present a need for appropriate Directives. The Directives related to the Flight Plan Conflict Probe, Airspace Probe, and Trial Plan Probe will depend upon the ground rules for related operations, and therefore, attempting to specify the probe-related Directives at this time would be premature.

For controllers, the probe-related Directives would be expected to undergo development as a routine change in ATC Handbook 7110.65 and related documents. It is expected that a supervisor's handbook similar in application to the Controller's Handbook will be in use by the time the probes become operational. Thus, the applicable

probe-related Directives for supervisors can also be treated as routine procedural changes.

Work Practices and Techniques

The probes may present new requirements for uniformity in the work habits and techniques among controllers. Trajectory Estimation can work only with the data available to it. Delays and inconsistencies in the timing and sequencing of manual inputs to the computer could affect the validity of the data on which the probes are calculated. A false data base would reduce the operational validity of the probe outputs, depending on how the probes process the available data.

While automated features such as ETABS might provide a significant measure of regularity and consistency of sector operation, other activities, such as coordination, will also need to be performed with the required uniformity even without automated aids. It is also possible that the required uniformity will involve higher levels of proficiency than otherwise might be the case. These effects will depend on the final ground rules and have not been analyzed at present.

Sector Workload Probe

The effects of Sector Workload Probe on Air Traffic Management would apply to the positions of operation to which the information would be sent and displayed, namely the Area Supervisor or the Area Manager. The actions that would be carried out at these positions in response to the information provided by Sector Workload Probe are not expected to be significantly different from existing actions affecting sectorization and positional manning. However, the information from the probe would affect the timeliness of these actions.

Therefore, no significant effects on supervisory staffing and manning seem involved. Sector Workload Probe would require appropriate changes in the Directives for the affected positions, and corresponding changes would be made in the supervisor's handbook.

OPEN ISSUES

There are still many unresolved issues which must be addressed in the process of implementing AERA 1, related to function performance, message display and input, testing, and other areas. Some of these issues are outlined below.

System Design Issues

This study describes how the AERA 1.01 functions may be implemented and used under routine control circumstances. The complete design of AERA in the AAS will need to consider non-routine circumstances as well. For example, the AERA design will need to deal with transactions between facilities, both other AERA facilities and non-AERA installations such as terminals. The AERA 1.01 functions are designed to operate within a single center's airspace, but there will be an operational advantage at some point in coordinating the implementation of the functions across center boundaries. For example, resolving aircraft conflicts near the center boundary may require knowledge about traffic in the next center.

Some of these boundary issues can be treated in AERA 1.01 by the specification of "Planning Regions" which extend beyond the center's airspace and therefore overlap. The proper extent of the Planning Region must be analyzed.

In certain cases, this look into the adjacent center's airspace could be a necessity, such as in the event of a catastrophic failure of the ATC system in that center. Overlapping coverage would then allow the adjacent centers to provide separation services to traffic in that area until the affected center could recover. Provisions will need to be made for those cases in which the automation is degraded; for example, the controller would need to be informed if the Flight Plan Conflict Probe or Airspace Probe functions were no longer available.

Functional Performance Issues

The performance of the functions will depend upon the type and accuracy of the data available to the functions, as well as the characteristics of the processing algorithms. Additional flight plan data that is not part of the present input data when an IFR flight plan is filed must be identified. This includes the accuracy requirements for both the present and the additional flight plan data.

The false and missed alarm rates of the probe functions must be realistically estimated considering the accuracy limits of all input data, including the limits placed on flight plan data above. The acceptable values for these false and missed alarms must be determined.

The complete specification of the capabilities of each function will not be achieved until additional testing can be performed. For

example, testing will probably be required to determine the preferred response of AERA to an out-of-conformance aircraft: drop the aircraft from consideration, since the trajectory is no longer accurate, or process it normally but with an indication that it is out-of-conformance, on the basis that even the inaccurate trajectory is still the best available estimate of the aircraft's intentions.

Operational Issues

Decisions about the characteristics of the advanced automation functions must consider the operational context in which the functions will be placed. Operational issues include items of controller responsibility, workload, training, and interaction with the new functions.

For example, the new probe functions are to be capable of detecting possible violations of separation standards earlier than the present ATC system and human controller can. It was stated earlier that the controller in whose sector the conflict would occur would have the primary responsibility for resolving it. Given the long look-ahead time of Flight Plan Conflict Probe and Airspace Probe, the aircraft involved may not be in the sector when the message is received. Any attempts to resolve the situation immediately may involve coordination between as many as three different controllers. Determining which controllers receive the advisory message concerning an Advisory Conflict, and which controller has the resolution responsibility for a conflict, still requires study.

The format of the advisory and alert messages, and the formats of all output messages from the computer and all input messages to the computer, are also candidates for further investigation. Principles of good design should be applied to make the input/output convenient, usable, and efficient.

The introduction of the new functions and new equipment needs to be planned carefully in order to disrupt operations as little as possible. Training must be carried out prior to implementation so that the controllers are familiar with the capabilities and limitations of the new functions. For example, the introductory training would need to stress the need to keep the aircraft trajectories up-todate, for the best possible performance of the conflict probe functions, as well as the continuing need for the controller to monitor for conflicts which the probes did not detect (e.g., those involving VFR or out-of-conformance aircraft).

It is the goal of the automation effort for any additional workload necessitated by the automation functions in one area to be offset,

or be more than offset, by other improvements. However, the actual effect of the automation functions on controller workload will not be known until operational testing can be performed.

TABLE OF CONTENTS

TABLE OF CONTENTS

CONCLUDED

LIST OF ILLUSTRATIONS

1. INTRODUCTION

In December 1981, the FAA published its plan for the development of the nation's air traffic control system over the next 20 years. The "National Airspace System Plan" [1], which was revised in April 1983, includes planning schedules for improvements to the en route and terminal control systems, flight services, navigation and surveillance systems, communications systems, and auxiliary systems--the entire National Airspace System.

1.1 Evolution of ATC Automation

One of the most significant improvements planned for the next 20 years is the early replacement of the computers currently used for Air Traffic Control (ATC). These computers, first installed nearly 20 years ago, will be replaced by modern "host" computers which will support the current NAS Stage A En Route* software with minimal changes. The additional capacity of the host computers will allow the introduction of several automation enhancements which are currently under development, such as Conflict Resolution Advisories and En Route Metering II. Also, new controller workstations known as Sector Suites will be introduced after the host computers have been installed.

The next stage of automation development after these host computers is referred to as the Advanced Automation System, or AAS, which is expected to provide a significantly enhanced control capability beyond NAS Stage A. The AAS will provide still more computing speed and capacity, by either expanding or replacing the host computers. In addition, new software will be provided for the AAS, including several new function which are referred to as AERA. The term "AERA" stands for "Automated En Route Air Traffic Control" and originally referred to a concept for full automation of the air traffic control function. While full automation of the air traffic control function may not occur, it is the goal towards which the ATC system will evolve.

The AERA functions will provide additional planning and control tools to the air traffic controller, in order to improve productivity and enhance safety while benefitting the airspace users.

*"NAS Stage A En Route" is the present en route ATC automation system. The acronym "NAS" stands for "National Airspace System."

AERA 1 will introduce these new software tools, providing planning aids to the controller to allow improved user services. AERA 2 will provide computer-aided decision-making tools for the controller, enhancing productivity and efficiency. In AERA 3, the computer is to be capable of predicting control problems such as aircraft conflicts, generating resolutions for those problems, and transmitting ATC clearances to the aircraft involved, with monitoring and only occasional intervention from the controller.

1.2 Evolution of the AERA Functions

Each of these three stages of AERA development is likely to be implemented in several steps. This process of gradual transition offers technical and operational benefits. New functions can be tested and proven in the field before the next automation package is introduced, reducing the developmental and safety risks. Controller confidence in the automation may also be enhanced if changes to the automated functions are introduced gradually and in a well-planned manner, with each new package building upon the capabilities and experience which had been developed previously.

A series of six AERA steps has been proposed and described in a recent MITRE report [2]. These proposed steps are briefly summarized in the following paragraphs.

AERA 1 consists of two steps, referred to as AERA 1.01 and AERA 1.02 (see Figure 1-1). AERA 1.01, the initial package of advanced automation features, is to be implemented as part of the initial Advanced Automation System of hardware and software. AERA 1.01 will consist of four functions:

- Trajectory Estimation will calculate the flight path of the aircraft in three dimensions (x, y, z) and time (t), based on information from flight plans and other sources.

- Flight Plan Conflict Probe will compare aircraft trajectories in order to test for conflicts between aircraft, situations in which aircraft separation minima are predicted to be violated.

- Airspace Probe will use the aircraft trajectory to test for conflicts with specific static adapted airspace volumes (special use areas and terrain).

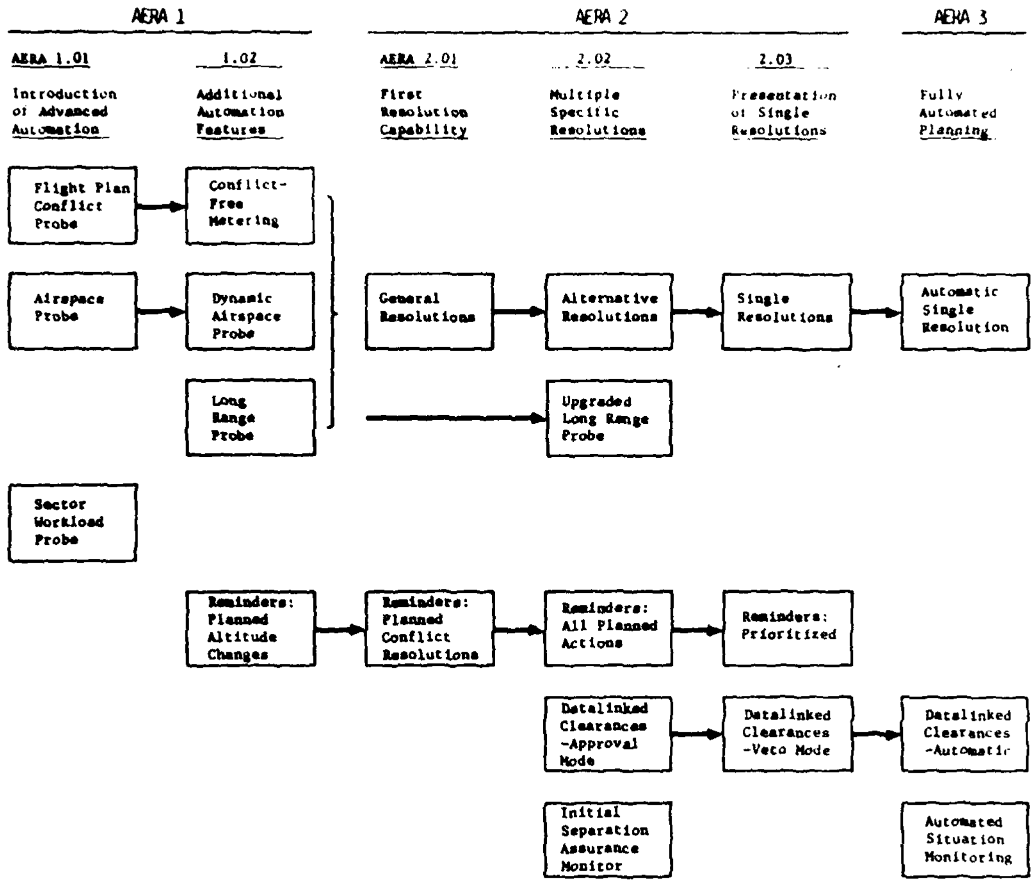


FIGURE 1-1
OVERVIEW OF THE AERA PACKAGES

- Sector Workload Probe will display various workload-related measures to supervisory personnel, to assist in determining sector manning levels and/or resectorizing as necessary to balance workload.

AERA 1.02 will add several new functions, and will start the process of integrating the advanced functions more closely with the existing functions. A Long Range Probe capability will be added, to help the controller evaluate off-airway route requests which extend beyond the prediction horizon of the Conflict Probe. The Airspace Probe will be enhanced to consider conflicts with dynamic weather areas, as well as with static areas of special use airspace. Metering advisories to the controller will be checked for potential conflicts before being displayed. The controller will be able to make more of the overall control plan known to the automation system, which in turn will provide reminders of planned actions at the appropriate time.

In AERA 2, these functions would be enhanced to provide improved controller productivity. Three steps are planned for AERA 2. The first, AERA 2.01, will introduce a computer capability for helping the controller to resolve those problems detected by the other advanced automation functions. Initially, this capability will consist of general advisories presented to the controller, with the controller adding the necessary details. For example, the resolution advisory could indicate the aircraft involved and the appropriate resolution maneuver, such as a climb, but leave it to the controller to specify the final altitude assignment. As these conflict resolutions are made known to the system by the controller, the system can help remind the controller to execute the different steps of the resolution at the appropriate time.

AERA 2.02 will see further enhancements to the resolution capability. The controller will be presented with several specific, complete resolutions; if one is selected, it will be automatically converted into a datalinked clearance, to be sent to the aircraft upon approval. This package will also include enhancements to the Conflict Alert function, allowing the aircraft trajectories to be considered as well as the radar tracks in determining if an imminent conflict exists. This capability is termed the Separation Assurance Monitor.

The next automation package sets the stage for the fully automated ATC system referred to as AERA 3. In AERA 2.03, only a single resolution is displayed to the controller. If the resolution is approved, it is translated into a clearance which is presented to the controller and automatically datalinked to

the aircraft unless specifically vetoed by the controller. The resolutions and reminders are assigned priorities by the system, based upon a global planning perspective.

Finally, full automation is applied to the ATC system, allowing route planning and resolution actions to be conducted without controller intervention. The controller is then left free to deal with special situations.

As the automation functions develop, the system is given more and more information about the controller's plan for the aircraft. This information in turn allows the system to help the controller to fulfill his plan. As the plan becomes more reliable as a predictor of future actions, the system's predictions of future problems become more reliable, enabling the controller to perform earlier and better planning. The evolution process may be characterized by this continuous improvement in the quality of planning for individual aircraft, due partly to improved surveillance data and better weather data, but mostly due to the integration of the automation system into the controller's planning and control process.

1.3 Impacts of AERA 1.01

The functions of AERA 1.01 represent the initial use of aircraft flight plan data to provide the controller with an automated strategic planning aid. The AERA 1.01 functions will not provide any services which cannot be performed today, but should permit a higher level of service to be achieved. For example, controllers presently use the fix posting times on the flight strips to detect situations in which two aircraft are expected to cross the same fix at the same time, and might therefore be in conflict. The Flight Plan Conflict Probe in AERA 1.01 performs essentially the same task, but for any point on the aircraft's trajectory and not just at fixes.

As a result, AERA 1.01 is expected to improve the ability of the ATC system to accommodate user-preferred altitudes and routes, including direct and off-airway routes. Flight Plan Conflict Probe and Airspace Probe are expected to reduce the workload involved with monitoring such flights and coordinating across sector boundaries.

These functions are also intended to help the controller be aware of a future separation violation earlier than in the current ATC system. There should therefore be more time in AERA 1.01 to develop an efficient and effective resolution. The

desired result is a smoother flow of traffic and a more even pace for the controller.

Although these benefits are expected from AERA 1.01, the net impact on ATC operations will probably not be large. Most of the benefits of advanced automation will not be realized until the later stages, after the AERA functions have been further developed and more fully integrated with the rest of the ATC system. The primary benefit of AERA 1.01 will be the introduction of the initial AERA functions, providing the necessary first step towards the greater benefits expected from full AERA implementation.

1.4 AERA 1.01 Environment

The discussion of AERA 1.01 in this report reflects some assumptions and current expectations about the characteristics of the ATC system at the time of AERA implementation. These design considerations are described below.

Most of this information has been obtained from the "National Airspace System Plan" [1] and the AAS Specification [3]. The schedules, descriptions, and other information presented in these documents represent the best available data about the future ATC system.

The AAS will be installed in Area Control Facilities (ACFs). ACFs will include facilities which resemble today's en route centers (ARTCCs), but which also handle some terminal airspace (ACF-A), and also facilities which primarily handle large blocks of terminal airspace plus some en route airspace, as in the New York area (ACF-B).

The advanced automation features of the AAS are planned to be installed initially in the ACFs, and will be used to serve Instrument Flight Rules (IFR) aircraft. Some of these aircraft may possess sophiscated avionics equipment; the AERA 1 functions should be designed so that such equipment is not required by the functions, but could be utilized if available.

By the time the AAS is installed, other new ATC-related systems are planned to be available. Mode S ground sensors will be installed which will provide coverage of all U.S. airspace above 12,500 ft. with greater accuracy than the present surveillance system. Mode S transponders, with a currently undefined level of datalink capability, will be installed in some aircraft. The Central Weather Processor (CWP) may be installed to provide improved processing and distribution of weather information.

These systems, and others, are planned to be available for integration with the functions of the Advanced Automation System such as AERA 1.01. However, the AAS should be flexible enough not to require these external systems but be able to operate satisfactorily with present-day surveillance, weather, and other systems.

1.5 Purpose and Scope of This Document

The purpose of this document is to describe the AERA 1.01 functions. The emphasis is on the functions' capabilities, which are described in greater detail than in previous AERA documentation. It is intended that a description of the AERA 1.01 functions at this level of detail will stimulate further discussion and consideration regarding the operational use of the functions, and that a process of refinement and revision will ensue which will ensure that advanced automation contributes to the development of a more efficient and effective ATC system. In order to help achieve this objective, the presentation includes, in addition to a discussion of the interrelationships of the AERA functions among themselves and with pre-existing automation functions, discussions of the effect of new automation tools on the way controllers provide ATC services. Considerations of the impact of AERA 1.01 on controller directives, work practices and procedures, and staffing and training policies are also included.

Consequently, this document will focus on the AERA 1.01 functions, although some discussion of the other functions in the AAS will also be necessary to explain the environment in which the AERA functions will operate. The implementation of AERA 1.01 and the internal design of its functions are not discussed here. The functions are considered in terms of their capabilities, rather than their processing structure. Detailed information on algorithms is contained in the AERA 1.01 Algorithmic Specifications [4, 5, 6, 7].

This document presents the present state of the AERA design. Issues relating to the operational use of AERA functions remain unresolved. In some cases, resolution of these issues depends upon details of the AAS design, most importantly with respect to the AAS Man-Machine Interface, which have not yet been established and which are beyond the scope of the current AERA design activities. Resolution of other issues depends upon achieving a better understanding of the impact of AERA on ATC operations. Extensive testing at MITRE and the FAA Technical Center is planned to assess the operational suitability of AERA functions. It can be expected that the definition of AERA

capabilities will undergo continued refinement as a result of these tests.

1.6 Structure of This Document

A functional description of the AERA 1.01 functions will be presented first, so that the intended use of the functions and their operation will be clear. Section 2 describes the four new functions to be introduced in the AAS and also describes the other functions which will have been implemented prior to the AAS. These other functions include NAS Stage A functions and NAS enhancements which are expected to be implemented in the host computers. Section 3 will describe the interfaces between the new functions and these other functions, between the AERA functions themselves, and between the AERA functions and the controllers and supervisory personnel.

Once the internal workings of the software functions have been described, the manner in which these functions appear to the individual controller will be discussed. Section 4 attempts to describe the way in which the controller will use the AERA functions to perform required tasks, and how those tasks will themselves be affected by the availability of the new functions.

Section 5 moves beyond the consideration of individual controllers to discuss the possible impacts of the new functions on the controller community as a whole. Training requirements, personnel policies, and control directives are considered.

By moving from the specific details about the functional design to the general impacts of the functions, this report attempts to provide a complete description of the AERA 1.01 functions as they are currently planned. However, a number of operational and implementation issues exist which cannot be answered at this stage of development. Some of these issues are presented in Section 6.

2. DESCRIPTION OF THE ATC FUNCTIONS IN THE AAS

The following paragraphs describe the different ATC functions that will comprise the initial implementation of the AAS software. The intended use of the AERA 1.01 functions will be described first, followed by brief descriptions of the other AAS functions. This will help to delineate what is included in AERA 1.01.

The design of the AERA 1.01 functions, and the interfaces between the functions, will be described in later sections. Section 2 describes what the functions do, Section 3 will describe how they do it, and Section 4 will describe how they are used.

2.1 The AERA 1.01 Functions

AERA 1.01 will consist of four functions:

- Trajectory Estimation
- Flight Plan Conflict Probe
- Airspace Probe
- Sector Workload Probe

These four functions are briefly described below.

2.1.1 Trajectory Estimation

The Trajectory Estimation (TJE) function augments the Route Conversion function in NAS Stage A to provide more accurate four-dimensional flight path estimates. Information from the aircraft's cleared flight plan is supplemented with available information about winds and temperatures aloft and other information from the AAS data base to produce a series of points in x, y, z, and t that define the aircraft's path through the ACF's airspace. Aircraft performance characteristics are used as available for a specific aircraft or from a general data base.

Amendments to a flight plan will trigger a reconversion (if needed) and reestimation of the balance of the flight's trajectory. If the difference between an aircraft's trajectory and its radar track position exceeds a parameter, as determined by the Flight Plan Association Checking task, an adjustment is made to the estimate of the aircraft's ground speed to account for the error prior to reestimating the trajectory from the aircraft's present position. This is referred to as "resynchronization."

The Trajectory Estimation function is critical to the successful implementation of AERA, since the probes require more accurate trajectory information than is available from NAS Stage A, especially in the vertical dimension. Trajectory Estimation also has a significant impact on the accuracy of the Metering function in the AAS.

2.1.2 Flight Plan Conflict Probe

The Flight Plan Conflict Probe (FPCP) function compares the trajectories of aircraft within the ACF Planning Region to look for future situations in which applicable separation criteria between aircraft may be violated. FPCP automatically monitors all controlled traffic within the Planning Region, which extends beyond the boundaries of the ACF to ensure thorough coverage of all flights.

Certain parameters based upon radar separation minima and required vertical separations are used to determine whether two aircraft might be in conflict. Enough information about the conflict will be presented to the controller at the appropriate time to help decide upon the best course of action.

The Flight Plan Conflict Probe function may also be invoked directly by the controller to probe a trial amendment for the aircraft. This capability is referred to as the Trial Plan Probe.

Once the resolution strategy in the form of a flight plan change has been determined by the controller, a trial amendment may be entered for the subject aircraft. The system generates a new Trial Trajectory incorporating the amendment; Flight Plan Conflict Probe is automatically invoked and proceeds to test the Trial Trajectory for potential conflicts. Appropriate messages and displays are routed to the requesting position. If the conflict has been resolved and no new conflicts detected, the aircraft may be given the new clearance, the trial amendment made current (i.e., a permanent amendment) by the controller, and the flight plan data base updated. Otherwise, the procedures may be repeated until the controller is satisfied with the resolution and accepts it.

The goal of Trial Plan Probe is thus to allow the controller the flexibility of testing various changes to a flight plan without committing the computer or aircraft to unneeded plan modifications.

2.1.3 Airspace Probe

Adapted within the data base of each en route facility's computer system are airspace volumes designated as Restricted Areas, Military Operation Areas, Warning Areas, etc. These designated special use airspaces have an altitude floor and ceiling, specific geographic boundaries, and times of activation/deactivation associated with them. Most aircraft are required to avoid these areas. Such airspace polygons can also be used to define terrain to be avoided.

The Airspace Probe (AP) function is designed to probe a flight throughout the Planning Region of the ACF to detect violations of the designated airspaces. The Airspace Probe is activated whenever the Flight Plan Conflict Probe is invoked, or when an adapted airspace region is activated by supervisory input.

If an airspace conflict is detected, a conflict message will be generated and displayed to the appropriate controller. The types of messages, and the controller response, will be discussed in Section 4.3.

2.1.4 Sector Workload Probe

Air traffic in a typical NAS en route center has some predominant flow characteristics--usually to and from major hub areas. The variations in these traffic flows are such that daily peaks and valleys may be anticipated, but short term fluctuations are difficult to predict in the current system. As an aid to managing the workload associated with the traffic peaks in a center, a method of predicting some workload-related measures at the sector level has been specified.

Sector Workload Probe (SWP) computes and displays these estimated measures to an Area Supervisor or Area Manager who can use them to help with decisions on sector manning or combining/decombining sectors. The workload measures are calculated for consecutive intervals up to a time limit (e.g., for each five minutes over the next hour).

2.2 Other Functions in the AAS Software

The previous section discussed the purpose of the AERA 1.01 functions which will be introduced in the initial implementation of the AAS software. These functions will be added to the set of other functions in the AAS. A majority of these other functions will be carried forward from NAS Stage A; although the coding will be different, and the algorithmic design may be

different from the current system, the purpose of these functions will not significantly change in the AAS. Other functions will be enhancements to present-day NAS Stage A which will have been introduced in the host computer. There will also be some additional enhancements which are currently planned to be introduced in the AAS but which are not considered part of AERA 1.01.

These ATC functions will be briefly described in the following subsections in order to complete the description of the automation system, emphasizing those which interface with AERA 1.01.

2.2.1 NAS Stage A Functions

The basic functional capabilities of the NAS En Route Stage A system consist of the Surveillance Data Processing capability, the Flight Plan Processing capability, and some additional functions including system support, backup and monitoring features. These are the primary ATC functions that exist in NAS Stage A now and will remain essentially unchanged in the AAS.

2.2.1.1 Surveillance Data Processing

The Surveillance Data Processing capability includes processing the raw data input, displaying the surveillance data to the controller, tracking the radar targets, and providing separation assurance functions based on the tracked targets.

The system processes all radar input messages from existing ATCRBS* sites and from newly developed Mode S sites. These input messages contain either target-related data, which is filtered, converted to a common coordinate system and passed on to the radar correlation and automatic tracking functions, or non-target messages, such as status and test messages, strobe messages, and weather messages.

Eligible target reports (radar data from ATCRBS or Mode S) are time corrected and correlated in three dimensions with track positions, the expected location of the radar target based on past returns. All tracks that are "paired" with an active flight plan are defined as controlled tracks; some additional processing is done to maintain association between the extrapolated position

*Air Traffic Control Radar Beacon System--refers to present-day Mode A and Mode C radar transponders.

of the flight plan and the aircraft track data. VFR (Visual Flight Rules) flights are not normally tracked by NAS; the AAS system, however, will track all beacon radar targets.

The track control functions allow the operational personnel to directly exercise control over the radar tracks associated with the aircraft. Responsibility for control of flights is transferred between control positions by means of the Handoff function. Track and flight plan data is transferred automatically or by manual input between sectors in an ACF, between adjacent ACFs, and between the ACF and an adapted TCF. In addition, a computer track may be initiated or re-initiated, may be "dropped" from the computer data base, or may be placed in "coast" mode, automatically or by manual input.

The radar track data is used by two functions of the automation system to help ensure the separation of IFR (Instrument Flight Rules) aircraft from other IFR aircraft (Conflict Alert function) and from terrain or other obstacles (Minimum Safe Altitude Warning function--MSAW). The Conflict Alert function monitors the predicted horizontal and vertical paths of all controlled IFR aircraft and issues a warning alert to the controller a parameter time (nominally two minutes) prior to a predicted violation of minimum separation between IFR aircraft. The MSAW function is designed to monitor aircraft position and altitude with respect to adapted terrain or obstacle areas in the ARTCC. Designated or special use airspace volumes may also be included in the adaptation data.

This surveillance data is presented to the controller on the Situation Display, also known as the PVD (Plan View Display) in NAS Stage A. The Situation Display presents a "picture" of the airspace containing fixed and dynamic data to ACF control personnel. The fixed items include geographic references, airways, navigation aids, etc. The dynamic data consist of track data blocks, radar history trails, non-correlated radar reports, and other surveillance messages.

2.2.1.2 Flight Plan Processing

The Flight Plan Processing capability accepts, checks, processes, and distributes flight plan data for individual flights. Active, pending, and prefiled flight plans are received by the system from local and remote sources. The ATC automation performs a series of checks to determine the validity of data items received in each message. The flight data is displayed to the controller and may be updated by him.

Flight plans may be entered into the AAS in a variety of ways: from external sources such as Flight Service Stations and other ACFs, or from the Bulk Flight Plan storage functions within the ACF. In addition, "Air Files" may be entered at pilot request by control personnel at the sector. All entered flight plans undergo acceptance checks and are automatically transmitted to appropriate facilities for departure, en route, and arrival processing.

Each flight plan and route amendment undergoes route conversion and extrapolation and is tailored to present all route data required at each sector. The Route Conversion function includes expansion of the filed route to include intermediate fixes and checking for valid and preferred routes. CTAs (Calculated Times of Arrival) will be computed in the AAS by the Trajectory Estimation function (see Section 2.1.1). Flight data including updated or amended plans are automatically transmitted to appropriate "downstream" sectors and facilities as required.

All controlled tracks (those paired with a Flight Plan) are subjected to a Flight Plan Association Check wherein the radar track position is compared with the Flight Plan position extrapolated to the same time. If the longitudinal deviation is within a parameter an incremental time correction is placed in the Flight Plan. When the parameter is exceeded, a resynchronization of the trajectory is performed (see Section 2.1.1). If the lateral deviation from the route centerline or the vertical deviation from assigned altitude exceed the associated parameters, an alert message is displayed to the controller.

As part of the new Sector Suites, en route sector positions will be provided with an electronic display of the flight plans called Flight Data Entries (FDE--analogous to paper flight strips). The capability to enter amendments to any part of the flight plan and to "mark" the FDE with special symbols, notes, and remarks will also be provided.

2.2.1.3 Additional Functions

Additional functions in the operational NAS Stage A system include functions to monitor and maintain the automation system itself, and such other features as the capability to:

- Adapt and utilize environmental data within the program system

- Allocate discrete beacon codes

- Provide simulated radar data for training

- Provide non-operational support for air traffic control

2.2.2 Near-Term NAS Enhancements

The preceding paragraphs described the primary functions of the ATC system as they are structured today. These primary functions will be augmented by several enhancements to the NAS Enroute Stage A system prior to the AAS and AERA 1.01. These include En Route Metering II (ERM II), Conflict Resolution Advisories (CRA), and an IFR/VFR Conflict Alert function, and may include an interface with the data link feature of the Mode S sensor system.

2.2.2.1 En Route Metering

The objective of En Route Metering is to organize arrival traffic at higher altitudes in the en route airspace so that congestion and delays in the terminal area are kept to a minimum. The en route metering package, called ERM I, that is currently implemented in the NAS Stage A system provides the capability for acceptance rate metering to one or more airports in the center with a uniform time separation between arrivals. The controller receives a display of the time at which each metered flight should cross its meter fix and the delay required to achieve that time. The controller, with the cooperation of the pilot, determines how and when the necessary delay is absorbed to meet the arrival goal.

The metering algorithm includes the generation of a landing sequence based on a first-come-first-served rule, determination and assignment of arrival slots at the meter point, and calculation of the amount of delay to be absorbed by each aircraft in the metered queue.

The upgraded metering package, ERM II, which is planned to be implemented in the new ATC host computer, offers significant additions to the functions of ERM I. These additions include the generation and display of advisories to the controllers suggesting how the required delay may be taken in a fuel-conservative manner, as well as advising the controller of the amount of required delay associated with the suggested advisory. The types of advisories generated are outer-fix advisories, speed reduction advisories, descent-control advisories, and holding advisories. An internal flight time estimation routine will be included to improve the accuracy of ERM II calculations.

In addition, metering advisories may be generated for display to controllers upstream from the arrival sectors, even to sectors located within another ACF. Metered aircraft are monitored in order to display the advisory at the appropriate time to effect the recommended delay tactic.

In the AAS Specification [3], the metering function is specified to include the capability to meter aircraft to a point or boundary as well as to an airport. Metering will also be performed to meet an arrival schedule or an in-trail separation distance, or an arrival rate as in ERM I and ERM II.

2.2.2.2 Conflict Resolution Advisories

The Conflict Resolution Advisory (CRA) function is designed to provide the radar controller with a display of possible alternatives for the resolution of conflicts identified by the Conflict Alert (CA) function. The prime objective of the CRA function is to reduce instances of operational error (a violation of en route separation standards) by reducing decision-making time in complex encounter situations. By displaying possible alternatives for the resolution of conflicts, the CRA function will generate/confirm the resolution preferred by the controller, who generally can introduce to the situation considerations beyond the capabilities of present day NAS automation (e.g., weather, communications failures, or the presence of uncontrolled VFR traffic). The initial implementation of the function is expected to be limited to only IFR-IFR conflicts.

According to the AAS Specification [3], CRA will be expanded in the AAS to also generate suggested resolution actions to avoid MSAW-detected conflicts with terrain and special use airspace.

2.2.2.3 IFR-VFR Conflict Alert

The current NAS Stage A Conflict Alert function applies only to IFR-IFR pairs. The IFR-VFR Conflict Alert function extends the Conflict Alert function to all pairings of Mode C-equipped uncontrolled (VFR) aircraft with controlled aircraft in en route airspace. The function automatically initiates and maintains tracks on uncorrelated Mode C beacon targets. These tracks are called "intruder tracks," but are not displayed to the radar controller unless in conflict with a controlled track. The conflict criteria for the IFR-VFR pairs may be different from the conflict criteria for the IFR-IFR pairs. Later implementation may incorporate IFR-VFR conflict situations as input to the Conflict Resolution Advisory (CRA) function.

2.2.2.4 Data Link Capability

An integral part of the Mode S secondary surveillance radar system is the capability to process data link messages between the Mode S site and Mode S equipped aircraft. Messages originating from the ATC system, as well as other facilities (Central Weather Processor, for example) may be sent to the appropriate Mode S site for transmission to the addressed aircraft. The Data Link capability is expected to be in the field in 1988, and some early implementation of selected messages should exist by the time the AAS is implemented.

Candidate messages for the initial application of data link include Automatic Handoff, Altimeter Settings, and Assigned Altitude confirmation. Handoff acceptance by a controller would generate a message to be uplinked to the aircraft containing the radio frequency of the accepting controller; altimeter setting would be automatically uplinked when changed; and assigned altitude would be uplinked when entered into the computer as a confirmation message to the aircraft. Other message types may also be implemented.

3. ADVANCED AUTOMATION AND THE COMPUTER--FUNCTIONAL DESCRIPTION

The functional elements of the AAS software and the role of each function within the ATC system have been explained in Section 2. The purpose of this section is to describe the internal organization of the four AERA 1.01 functions discussed in this document. The description will include discussion of the interfaces of the new functional elements with the other ATC functions (referred to here as the "external" interfaces) as well as the internal interfaces between the elements. Figure 3-1 depicts these four functional components and their relationships to each other and to other ATC functions.

The following descriptions of the components and their interfaces are based on the current algorithmic designs, as referenced, and are subject to revision as development of the functions continues.

3.1 Functional Components

3.1.1 Trajectory Estimation

The Trajectory Estimation component is responsible for the construction of the four-dimensional (x, y, z, t) aircraft trajectories. It may be called upon to create a trajectory for two different reasons: because a new plan was received or because an update of an existing plan is required. The TJE component includes two separate subfunctions, Nominal Plan Builder and Trajectory Construction.

Nominal Plan Builder is tc be activated when a flight plan is received from the Route Conversion function, for the purpose of creating a list of "Planned Actions" which reflect pilot intents implied by the flight plan and by ATC standard operating procedures implicit in transitioning the Planning Region. These Planned Actions are to indicate, for example, where changes in altitude would occur, based upon data in the flight plan and any applicable ATC operating rules (such as those specified in Letters of Agreement). An example of such a Planned Action would be the change in altitude for a descent to the destination airport. After creation of this list, both the list and the horizontal plan are passed to Trajectory Construction.

Trajectory Construction then merges the converted flight plan with the list of Planned Actions, taking into account weather factors and aircraft performance data. Trajectory Construction is to be activated either to process a flight plan its Planned Action list from the Nominal Plan Builder or to process

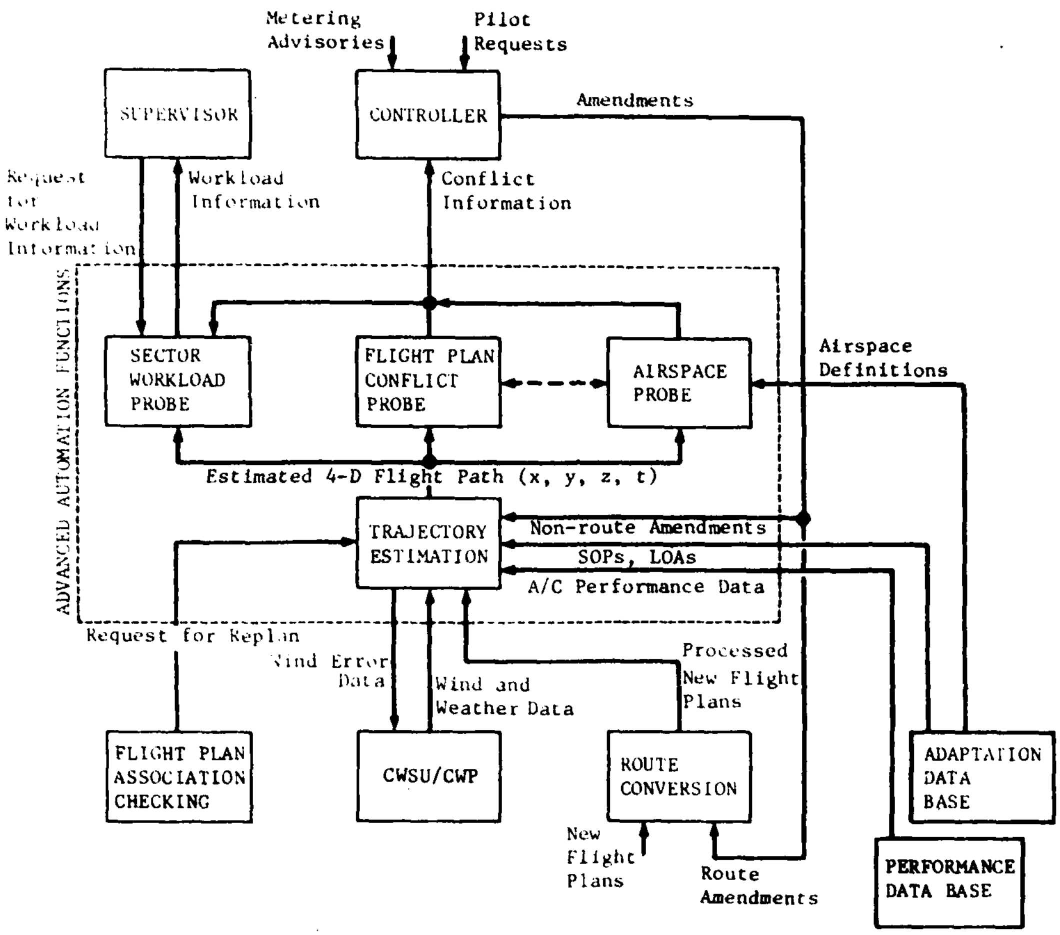


FIGURE 3-1
FUNCTIONAL INTERFACES OF AERA 1.01 COMPONENTS

an amended plan (a replan). A replan request contains identification of the current plan and a new or updated list of Planned Actions, and may be generated manually by a controller input or automatically by the Flight Plan Association Checking function. A replan request is generated automatically to resynchronize a plan when the Flight Plan Association Checking function detects a longitudinal error of sufficient magnitude between the tracked position and the flight plan trajectory. Resynchronization is to be performed by the Resynchronization Replanning subfunction of TJE.

The modeled trajectory is composed of a sequential list of points representing a four-dimensional estimate of aircraft position at all locations along the cleared route of flight within the Planning Region. Implicit in the segment between adjacent points are the pertinent attributes of the aircraft along that segment, such as its speed, heading, acceleration and altitude transition rate as well as the x, y, z position coordinates and time at both points.

The output of the TJE component (the completed aircraft trajectory) is stored in the system data base where it will be subsequently accessed by the components requiring the trajectory as input.

Trajectory Estimation in AERA 1.01 will be able to model the path of an aircraft on radar vectors if the details about the maneuver can be adquately specified. For example, a pilot-requested deviation from the route, such as a lateral offset, may be specified by the controller through a route amendment message.

If the aircraft deviates from its trajectory and exceeds the lateral conformance parameter, automatic longitudinal updating of the trajectory will cease. However, when that aircraft returns to lateral conformance, trajectory resynchronization should occur, triggered by the accrued longitudinal deviation resulting from the extra distance flown.

Additional information on the TJE may be found in the algorithmic specification [4].

3.1.2 Flight Plan Conflict Probe

This functional component uses the estimated trajectories of controlled aircraft to test for future violations of separation criteria between a specified subject aircraft and other (object) aircraft trajectories in the ACF Planning Region. Flight Plan

Conflict Probe is automatically triggered by the activation of a new flight plan, by an amendment to an existing flight plan, or by a CTA (Calculated Time of Arrival) update to a current flight plan. It may also be manually invoked for a Trial Plan Probe.

According to the algorithmic specification [5], FPCP when activated will use a coarse filtering process to eliminate those flights that are too far removed from the subject to be considered in further prediction processing. The purpose of the coarse filter is to minimize execution time of the overall prediction process by quickly discarding those object aircraft which could not possibly contribute to a conflict with the subject aircraft.

Object aircraft which pass through the coarse filter are termed "nominees" and are eligible for further processing. As such, they are passed on to the next step in the prediction process--the fine filter. The fine filter's job is to examine those segment pairs identified by the coarse filtering process to determine if the applicable separation criteria will be violated. If the fine filter ascertains that the separation criteria will be violated, the predicted violation is classified as an "encounter," and a description of the violation is stored in an encounter data base. Not all encounters immediately meet the criteria for display to a controller (the predicted violation may be too far off in the future, for example), so the encounter will be further examined to determine when to notify the controller. At the proper time, information from the encounter data base will be displayed to the appropriate controller(s) for attention.

3.1.3 Airspace Probe

This component uses the estimated trajectory of a specified subject aircraft to predict future entry of that aircraft into particular types of active special use airspace or into close proximity with terrain or other violations of specified minimum altitudes. Like FPCP, it is to be activated to probe for violations by a particular (subject) aircraft when the trajectory for that aircraft is first created, whenever the trajectory is modified, or as part of a Trial Plan Probe.

In the above mentioned cases, the Airspace Probe is performed automatically in conjunction with Flight Plan Conflict Probe; however, it may also be executed independently of FPCP following an activation/deactivation of a designated airspace. When this occurs, all eligible flights in the system are to be probed for changes in conflict status with regard to that particular volume of airspace.

The designated airspaces (Restricted Areas, Military Operation Areas, Warning Areas, MSAW polygons, etc.) are to be adapted with an altitude floor and ceiling, specific geographic boundaries, and the times of activation/deactivation. Descriptions of these areas are maintained in the data base as airspace polygons. The description data include the geographic definition of the polygon as well as such other identifying information as the airspace ID, sector numbers of the sector(s) containing the polygon, and the scheduled times of activation and deactivation.

Airspace Probe will predict violations of special use airspace or terrain areas by comparing the trajectory of the subject aircraft against all airspace and terrain polygons. As in Flight Plan Conflict Probe, a coarse filtering process is implemented to quickly eliminate those polygons which are not in close proximity to the aircraft's flight path. This process may utilize data structures constructed during the execution of Flight Plan Conflict Probe (notably a correlation between segments of the aircraft's trajectory and a grid overlaid on the Planning Region). The output of the coarse filter is a list of polygons ("nominees") which are passed to a fine filter. The fine filter tests for actual intersection of the polygons by the flight path, taking into account applicable altitude bounds and activation times of each polygon. Any violation thus detected is referred to as an encounter, and a description of the violation is stored in the encounter data base. At the appropriate time, this information is displayed to the controller. A detailed description of the Airspace Probe process may be found in the algorithmic specification [6].

3.1.4 Sector Workload Probe

This functional component evaluates the expected (future) workload of a sector or sectors in order to provide the Area Supervisor or Area Manager with advance warning of significant changes to workload. Given enough advance notice, the supervisor may formulate, in a timely fashion, a plan for handling the workload (such as decombining sectors or providing additional manning for the overloaded sector). According to the algorithmic specification [7], the Area Supervisor or Area Manager may request an immediate display of the current and projected workload measures for any sector or set of sectors, request that the measures be displayed periodically or request that SWP provide an advisory when a selected measure exceeds or falls below a specified threshold value. SWP will update its base of information internally upon a resectorization, when a new flight plan is added to the center data base, or whenever an existing flight plan is modified.

To assist the supervisor in evaluating workload for a sector, Sector Workload Probe calculates the following types of information for each requested time interval:

- a weighted sum of planned ATC actions
- the number of aircraft
- the number of projected aircraft encounters
- a traffic density measure

In addition, a single aggregated measure will also be available.

3.2 External Interfaces

Since the advanced automation functions will not constitute a stand-alone system, but rather comprise a set of new functions which operate within the framework of the AAS, implementation of these functions necessitates acquisition of input data from existing ATC system functions and the return of function output to the system after processing. Examination of Figure 3-1 will show that, in general, most of the input data required from other ATC functions will be needed for the Trajectory Estimation process and most of the data output from the new components will be presented to the controller or supervisor.

Discussion of the external interfaces is presented in two parts: interfaces with other automated functions and interfaces with the human element (controller or supervisor).

3.2.1 External Interfaces with Other Automated Functions

The AERA 1.01 functions receive the following types of input data from other automated functions and system data bases: flight plan data, aircraft performance data, weather information, and special use airspace definitions. The first three types of data are inputs to the Trajectory Estimation function and are used in constructing the four-dimensional aircraft trajectories. The special use airspace definitions are used by Airspace Probe in the detection of airspace violations. In addition to the input data, Trajectory Estimation may receive a request for replan due to the need for resynchronization.

3.2.1.1 Flight Plan Data

Information on new flights or current flights with route amendments is received from the AAS Route Conversion function in the form of processed flight plans. When these plans reach TJE, they have been validated and have undergone route conversion.

The converted plan is a horizontal route plan which consists of the pilot's original filed plan, modified to accommodate established changes such as preferential routes (PDARs, PARs, etc.) or Severe Weather Avoidance Plans, and then translated into a sequence of (x, y) points. New flight plans requiring conversion may be obtained from several sources: manually entered by the controller, from Bulk Store at the ACF, from Flight Service Stations (via TTY entry) or from neighboring facilities (via computer crosstell messages). The converted plan for a current flight with a pending route change is received from Route Conversion following amendment of the route by the controller. The request for replan of a current flight plan for the purpose of resynchronization is received when the (external) Flight Plan Association Checking function detects a longitudinal deviation of the aircraft with respect to its planned trajectory.

3.2.1.2 Aircraft Performance Data

Aircraft performance data is used by TJE to create a trajectory based on the expected performance of a particular aircraft or class of aircraft. The data may include such information as a family of climb and descent gradients (minimum to maximum), aircraft turn rates, bank angles, cruise acceleration rate, maximum altitude, and minimum and maximum speeds (by altitude). The performance data is contained in an aircraft performance data base where it will be accessed by TJE. In AERA 1.01 this data base may consist of relatively static tables of general characteristics (per aircraft type) obtained from manufacturer's and airlines' specifications; if data is available for individual aircraft, that data will also be stored in the data base. By retrieving aircraft characteristics data from this data base, TJE will be using the best available data in calculating trajectories.

3.2.1.3 Airspace Definitions

The Airspace Probe, in order to detect violations of special use airspace or conflicts with terrain, requires definition of the special use areas. This information will be contained in an adapted data base and consist of such data as identification of the areas (e.g., by name or number), a geographic description of the polygons representing the areas, activation times, and applicable altitudes.

3.2.1.4 Weather Data

The Trajectory Estimation process also makes use of weather information when constructing trajectories. This information (winds aloft and temperatures aloft) may be obtained from the Central Weather Processor (CWP), which has consolidated information from the National Weather Service, pilot reports, and other sources. The weather information will be stored in the weather data base as a three-dimensional grid enveloping the Planning Region airspace and be updated periodically.

The Trajectory Estimation process may provide feedback on wind information. Wind error accumulation information, deduced from aircraft deviation data, would be supplied to the the Center Weather Service Unit (CWSU) for evaluation and possible use.

3.2.2 External Interfaces with Controller or Supervisor

The AERA 1.01 functions have a number of interfaces with the controller or supervisor (either the Area Supervisor or Area Manager, or another supervisory position as appropriate). These interfaces are identified here and are discussed in more detail in Section 4.

3.2.2.1 Controller Interface

The controller is responsible for updating the trajectory data base to reflect all clearances given to, and acknowledged by, aircraft under his control. This is done by entering flight plan amendment messages whenever a change is made to either the aircraft's current clearance or to the filed flight plan. Input of these messages is an extremely important interface because it keeps the projected trajectories in close correspondence with the ATC clearances as known by the pilot, which improves the accuracy with which the probe functions can detect conflicts.

At the controller's option the flight plan amendment may be applied to the current plan for the specified aircraft (in which case the data base would be changed to reflect the change) or the amendment may be treated as a trial amendment (in which case a trial trajectory would be created to incorporate the change and the current trajectory would remain unchanged). Flight plan amendment messages may be entered by the controller for several reasons: to resolve conflicts, to implement a metering advisory, to test out the effects of a trial amendment, or because a pilot requested a flight plan change. Amendment messages will need to contain identification of the aircraft plan to be changed, an

indication of whether the change is to be a trial change or an actual change to the data base, and the details of the change.

The output to the controller consists of the conflict information processed by the conflict probes (Airspace Probe and Flight Plan Conflict Probe). Identification of detected conflicts is to be presented on the controller's display. Additional information regarding a particular conflict situation may be available to the controller upon request, and may include a graphic display of the conflict situation.

3.2.2.2 Supervisor Interface

The supervisor, either the Area Supervisor or Area Manager, interfaces with the Sector Workload Probe to obtain workload information for a particular sector or sectors. This information is displayed as a result of either an immediate request from the supervisor or a supervisor programmed request, such as "Update and display the data every M minutes" or "Warn me if measure X for sector Y exceeds value Z." Output to the supervisor consists of the presentation of the data from the Sector Workload Probe in the form of Sector-specific reports, covering specified time intervals.

3.3 Internal Interfaces

The functional internal interfaces, i.e., the relationships between the advanced automation functions, are illustrated in Figure 3-1. Trajectory Estimation has no internal source of input data (all of its input was described in the paragraph on external interfaces), but it does provide output to the other three AERA 1.01 functions, in the form of aircraft trajectories.

Both Flight Plan Conflict Probe and Airspace Probe receive the trajectories from Trajectory Estimation as one of their inputs, and both produce a description of detected conflicts as their output. This description of conflicts is stored in the data base for other users, such as display processors and Sector Workload Probe. In addition, Flight Plan Conflict Probe and Airspace Probe may share the results of the coarse filtering process used to select nominees for conflict prediction processing.

Sector Workload Probe has three internal sources of data: the aircraft trajectories from Trajectory Estimation and the conflict information from Airspace Probe and Flight Plan Conflict Probe. It has no internal AERA interface for its output, but other users such as display processors may access its data.

4. ADVANCED AUTOMATION AND THE CONTROLLER--OPERATIONAL DESCRIPTION

Both the new and existing automation functions described in the previous sections have the same basic purpose: to help the controller handle traffic in a safe and expeditious manner. The role of the individual functions in achieving this goal, as described in Section 2, drives the design of each function and the interfaces with other features (Section 3).

One of the most important interfaces of the AERA 1.01 functions will be with the human element of the ATC system, principally the controllers and supervisory personnel (e.g., Area Supervisors and Area Managers). Some of the data flows from the functions to the human element have already been mentioned. This section will discuss how that data may be used by controllers and supervisors in performing their tasks, how the new functions will provide new control tools and the impact of those tools on the controller's and supervisor's responsibilities.

4.1 New Control Tools

For this discussion, an air traffic control tool will be defined as an automated aid which is visible to the controller and which assists in the performance of control tasks.

From the controller's point of view, four new tools will be introduced by AERA 1.01:

- Flight Plan Conflict Probe
- Airspace Probe
- Sector Workload Probe (for supervisors)
- Trial Plan Probe

Three of these tools are directly linked by name to three of the new functions of the AAS. The fourth tool, Trial Plan Probe, is a controller-initiated version of the Flight Plan Conflict Probe and Airspace Probe sequence. The other new function, Trajectory Estimation, does not produce a direct, visible control tool, but is an integral part of all the new tools.

The operational description of the AERA 1.01 tools is predicated on the following ground rule assumptions:

- The controller will continue to be ultimately responsible for detecting and resolving all conflicts. Where they are applicable, however, the probe functions are intended to be the principal conflict-detection tool.

- The probes produce valid results only when the aircraft are in conformance with their flight plans. When an aircraft is out-of-conformance, the controller will be expected to reestablish conformance as quickly as possible. (How the probes deal with the trajectories of out-of-conformance aircraft must still be determined.)

- The AERA 1.01 tools will not replace or displace any other automated or manual tool or function, but will augment these tools.

- Conflicts will be detected by the probes using parameters based on radar separation minima and vertical separation minima, not on other types of non-radar separation minima.

- The probes will introduce new displays or lists, new actions, new procedures, and will imply new directives.

The purpose of the following section is to present a description of the AERA 1.01 tools from the controller's point of view. The following issues will serve as a focus for the discussion.

- How much of the controller's job is affected by the tools?

- How does the controller use the tools?

- How do the tools help the controller fulfill his responsibilities?

- What new tasks are imposed by the tools?

- How do the tools fit in with the controller's other activities?

4.2 Controller Tasks and Control Environment

The next several paragraphs summarize the controller's responsibilities and control environment in order to examine the impact of the AAS and provide a background for understanding the operational usage of the new tools.

4.2.1 Controller Functional Areas of Responsibility

The new tools of the AAS will assist the controller in fulfilling high-level, functional responsibilities, such as detecting conflicts or issuing conflict-free clearances, rather than those

mechanical tasks that are performed in the course of handling aircraft. In order to analyze what parts of the controller's job will be affected by the new tools, it is useful to group individual activities that the controller performs into such functional areas. Within each area, there is a consistent set of goals--keep aircraft separated or expedite the flow of traffic to destinations, for example. These functional areas provide a structured framework within which the various activities and tools of the controller's job can be understood and the impact of the AAS can be assessed.

The controller's job can be divided into seven functional areas or tasks, as follows:

- Monitor Traffic
- Maintain Aircraft Separation
- Formulate and Issue Clearances
- Transfer Control and Communications
- Meter Traffic
- Respond to Pilot/Controller Requests
- Issue Safety Advisories and Informational Messages

This is not the only possible categorization, of course.

The above tasks are defined in broad terms so that, taken together, they encompass the vast majority of the activities the controller performs day to day. To the extent that one set of activities is required to meet the goals of another task, some of the tasks overlap.

While the controller's overall job is important, some tasks are more critical than others in the sense that the critical tasks must be performed continuously or without delay to insure aircraft safety, while other tasks may be postponed temporarily if necessary. The following priority scheme has been adopted in the task descriptions.

- The tasks that must always be performed continuously or without delay and which are safety-related are labeled as <u>Priority One</u>. Under certain circumstances, these tasks are performed before all other tasks.

- The tasks that are concerned with the expeditious flow of traffic and which are important to the maintenance of order and control in the ATC system are labeled as <u>Priority Two</u>. These tasks are important but, under heavy workload, are performed after aircraft safety has been assured through Priority One tasks.

- Priority Three tasks are identified as additional services in the Controller's Handbook (FAA Handbook 7110.65C [8]), and are to be performed on a workload-permitting basis only. These tasks provide assistance to the pilot, but are not directly involved in issues of safety or control.

AERA 1.01 affects mainly Priority One tasks. To the extent that control functions (Priority Two) include safety-related tasks (Priority One), they also are affected by the AERA 1.01 tools.

The task descriptions below include a description of the controller's responsibilities vis-a-vis the task, the priority level of the task, and the applicable AERA 1.01 and pre-AAS tools, for each of the functional areas:

1. Monitor Traffic

   Controller responsibilities: Maintain awareness of the current traffic situation, impending changes, and system environment. In particular, note possible conflicts, clearance deviations, safety violations, equipment failures, and weather cells.

   Priority level: One

   Advanced Automation Tools: Flight Plan Conflict Probe, Airspace Probe

   Pre-AAS Tools: Conformance Monitor, Conflict Alert, MSAW, IFR-VFR Conflict Alert

2. Maintain Aircraft Separation

   Controller responsibilities: Provide, at all times, at least one separation service (lateral, longitudinal, vertical, radar) for every pair of controlled aircraft within the jurisdiction. Insure separation between those aircraft and all active, special use airspace within the jurisdiction.

   Priority level: One

   Advanced Automation Tools: Flight Plan Conflict Probe, Airspace Probe, Trial Plan Probe

   Pre-AAS Tools: Conflict Alert, MSAW, IFR-VFR Conflict Alert, Conflict Resolution Advisories

3. Formulate and Issue Clearances

Controller responsibilities: Generate clearances that satisfy some stated goal (e.g., resolve conflict, respond to pilot request, meter aircraft). Review the clearance to detect any inherent potential problems. Issue clearances to aircraft that will allow aircraft to travel on conflict-free routes.

Priority level: One

Advanced Automation Tools: Trial Plan Probe

Pre-AAS Tools: Conflict Resolution Advisories

4. Transfer Control and Communications

Controller responsibilities: Transfer control of an aircraft at a prescribed location, time, fix, or altitude after eliminating all potential conflicts between the aircraft and other aircraft under current control. If radio communications are to be transferred, transfer radio communications before aircraft enters next sector and after control has been transferred.

Priority level: Two

Advanced Automation Tools: (none)

Pre-AAS Tools: automated handoff function

5. Meter Traffic

Controller responsibilities: Establish the sequence of arriving aircraft by requiring them to adjust flight operations as necessary to achieve proper spacing. Formulate and issue clearances to implement proper spacing (see Task 3).

Priority level: Two

Advanced Automation Tools: (see Task 3)

Pre-AAS Tools: ERM II (see Task 3)

6. Respond to Pilot/Controller Requests

Controller responsibilities: Approve or disapprove operational requests generated by pilots and controllers as circumstances permit. Formulate and issue clearances as required (see Task 3).

Priority level: Two

Advanced Automation Tools: (see Task 3)

Pre-AAS Tools: (see Task 3)

7. Issue Safety Advisories and Informational Messages

Controller responsibilities: Issue safety advisories as necessary on a first priority basis and issue messages generated by additional services on a workload-permitting basis.

Priority level: One, three

Advanced Automation Tools: (none)

Pre-AAS Tools: IFR-VFR Conflict Alert, Conflict Resolution Advisories

4.2.2 Control Environment of the En Route Controller

The en route controller using the advanced automation tools will be operating within the Sector Suite work station--in fact, the Initial Sector Suite System will already be operational and in use before the introduction of the AAS. A Sector Suite is the operational equipment which one or more controllers use to control traffic for a sector. The Sector Suite itself consists of from one to four common consoles, each containing a main display and an interactive display (a logical display which may be physically located on the main display). In addition, each Sector Suite will include one or more random positioning devices (trackball or joystick), keyboards, and voice communications panels.

The presently used paper flight strips will be replaced by electronic Flight Data Entries (FDEs) on one of the console displays and an interface mechanism will be available to the controller to interact with these "strips." As in today's work station, the controller will have the ability to construct and

enter messages into the system and to dynamically change the display of data on his screens.

A number of logical displays required by the controller have already been identified in the AAS Specification [3]. These logical displays describe the functional groupings of information presented to the controller as a single entity. The displays thus far specified include the following:

- Situation Display--geographic and track data, as in today's PVD

- Flight Data Display--flight information for aircraft of interest to the controller (similar to today's flight strips)

- Aeronautical and Meteorological Data Display--information directly affecting flight operations but not related to a specific flight such as (textual) weather data and special use airspace information

- System Status Data Display--dynamic information regarding the status of ATC equipment, operational areas, airports, etc.

- Metering Advisory List Display--information and advisory data calculated by the en route metering function

- Alert and Resolution Display--information on alert or warning conditions detected by the system or input by the controller and that information necessary for resolving the alert condition; functionally same as in NAS Stage A

- Special List Display--compact lists for quick scanning by the controller (includes departure list, inbound list, hold list, beacon code selection list, etc.); functionally same as in NAS Stage A

- Message Composition and Response Display--made up of two displays: a message composition display which contains a message preview area and a menu area, and a response display which contains computer responses to controller-input messages or queries; similar to CRD in NAS Stage A

- Airport Environmental Data Display--data from environmental sensors

- Static Information Display--data that change infrequently (on the order of months)

- Weather Display--weather areas as obtained from the Central Weather Processor

- Flow Control Situation Display--plan view of a geographic area that is of concern to a controller or supervisor

- Oceanic Situation Display--plan view of a geographic area of interest to an oceanic controller

- Sector Workload Display--information on the expected workloads at all the sectors in the facility

The incorporation of the AERA 1.01 functions into the ATC system will generally not require new logical displays, although details of the design of the displays will be affected.

Messages entered by the controller to interface with the new functions will still utilize the Message Composition and Response Display (and responses to queries will also appear on this display). The messages from the Airspace Probe and Flight Plan Conflict Probe can appear on the Alert and Resolution Display and will be distinguishable from other messages there.

However, there may be a need for an additional logical display to accommodate graphic information relating to a future event (such as a probe-detected conflict). The controller may desire more information about a situation than is given in the brief description on the Alert and Resolution Display. The controller should be able to request this additional information, which may take the form of a graphic description (as well as additional textual information) on one of the displays.

4.3 Use of the Advanced Automation Controller Tools

The following paragraphs discuss the operational usage of the new tools of the AAS. Each tool's interface with the controller or supervisor is discussed separately. Appendix A contains detailed step-by-step descriptions of several controller tasks to show how the AERA 1.01 tools may be incorporated.

These descriptions represent a preliminary concept for operational implementation of the new tools. The descriptions are presented to stimulate discussion, and are subject to change as a result of testing or further investigation.

4.3.1 Flight Plan Conflict Probe

4.3.1.1 Description

The Flight Plan Conflict Probe assists the controller in detecting and identifying the details of situations where separation minima between aircraft may be violated. The Flight Plan Conflict Probe is a strategic tool in that it assists the controller in prediction and resolution of situations in which the time-to-violation is relatively long, as opposed to the Conflict Alert function which identifies imminent conflicts (less than two minutes to violation).

The current definition of "conflict" is any situation in which applicable separation minima may or will be violated. The controller's responsibility with respect to conflicts is to resolve them promptly. With today's non-automated methods of conflict prediction, conflicts will be detected, for the most part, only when the predicted point of violation occurs within the sector in which the involved aircraft are flying or within the adjacent sector. Since the time to violation is relatively short in these situations, and since the certainty that, if the situation is left alone, a violation will occur is relatively high, the controller is directed to resolve the situation promptly.

The automated probes add a new dimension to the subject by detecting situations in which separation minima may be violated much further in the future. Though these situations fit the current definition of "conflict," they are different from "conflicts" detected in NAS Stage A in two important ways. First, because of the longer lookahead times, the estimates of future aircraft position are more subject to variations in winds and aircraft performance, and thus there may be less certainty that a separation violation will occur if no control action is taken. Secondly, the long lead time may reduce the need for prompt resolution. Requiring the controller to resolve all such situations promptly may increase workload without significantly increasing system safety. It is therefore useful to create a new category of "possible problem areas" to include these situations which do not <u>require</u> prompt resolution.

Such situations will be referred to in this document as "Advisory Conflicts." Though the controller would not be required to resolve all such situations immediately, knowledge of them may be useful to his planning activities. The controller may want to devote extra attention during monitoring tasks to the possible problem, and may plan aircraft movements in such a way as to

reduce the likelihood of an actual separation violation developing. If, on the other hand, prompt action by the controller is deemed necessary to avoid a separation violation, this situation will be called a "Priority Conflict." Priority Conflicts would be recognized as conflicts in NAS Stage A; Advisory Conflicts would probably not be considered conflicts today.

The two types of situations that are detected by the Flight Plan Conflict Probe, Advisory Conflicts and Priority Conflicts, will be identified to the controller through advisory and alert messages, respectively. These messages may be sent to the "involved" controllers, where an "involved" controller is one who meets one or more of the following criteria:

- The controller has computer control of one or both of the aircraft involved.
- The controller is in radio contact with one or both of the aircraft involved.
- One or both of the aircraft is in the controller's airspace.
- The predicted point of violation is in the controller's airspace.

The recipients of the messages, the content of the messages and the related controller responsibilities are discussed in the following two sections.

4.3.1.2 Aircraft Violation Advisory Message

When an Advisory Conflict is detected by the Flight Plan Conflict Probe, an advisory message is sent to one or more of the involved controllers, although it is not clear at this time which of the involved controllers should receive the information. Particularly in complex situations such as ones in which the aircraft involved are currently in different sectors and the predicted point of violation is in a third sector, the issue of who gets the advisory message is non-trivial and subject for study.

The controller who does receive the advisory message uses it for informational purposes. The advisory message is primarily a notice to the controller to be aware of and monitor the situation closely because it may develop into a Priority Conflict. The controller may optionally take measures to resolve the

situation, but such measures would probably be considered an additional service.

The advisory message contains information necessary for the controller to identify the Advisory Conflict. The message may contain such data as identification of aircraft involved, location of predicted violation, time of violation, and IDs of sectors with current control of the aircraft involved. Additional information which would be useful in resolving the situation may be available to the controller via an auxiliary display which may include, for instance, a graphical representation of the situation. An explicit controller action would be required to access the additional information, such as an entry on the interactive display.

4.3.1.3 Aircraft Violation Alert Message

The alert message informs the controller of a Priority Conflict detected by the Flight Plan Conflict Probe. It identifies the conflict to the controller by presenting the same information as is included in the advisory message. Additional information may be available on an alternate display, as for Advisory Conflicts.

With Priority Conflict situations, a control directive will be required to assign responsibility for initiating the required coordination and for resolving the conflict. In most cases it is expected that the alert message will be sent to the controller in whose sector the violation is predicted to occur, and possibly to other involved controllers. The assignment of responsibility is subject to modification and elaboration as a result of further study.

The controller's responsibility with respect to any Priority Conflict situation, whether it is detected by an automated probe or by mental monitoring activities of the controller, will be to resolve it promptly, as established by the appropriate directives. The Flight Plan Conflict Probe will provide information on the Priority Conflicts detected that will assist the controller in forming resolutions. The controller uses the information provided by the probe and his own knowledge of the situation and ATC rules to formulate an appropriate resolution, evaluate the implications of the resolution (possibly with the aid of the Trial Plan Probe, see Section 4.3.3), revise the clearance if necessary, and implement the clearance by coordinating with the pilot and, if necessary, other controllers. This process is diagrammed in Figure 4-1.

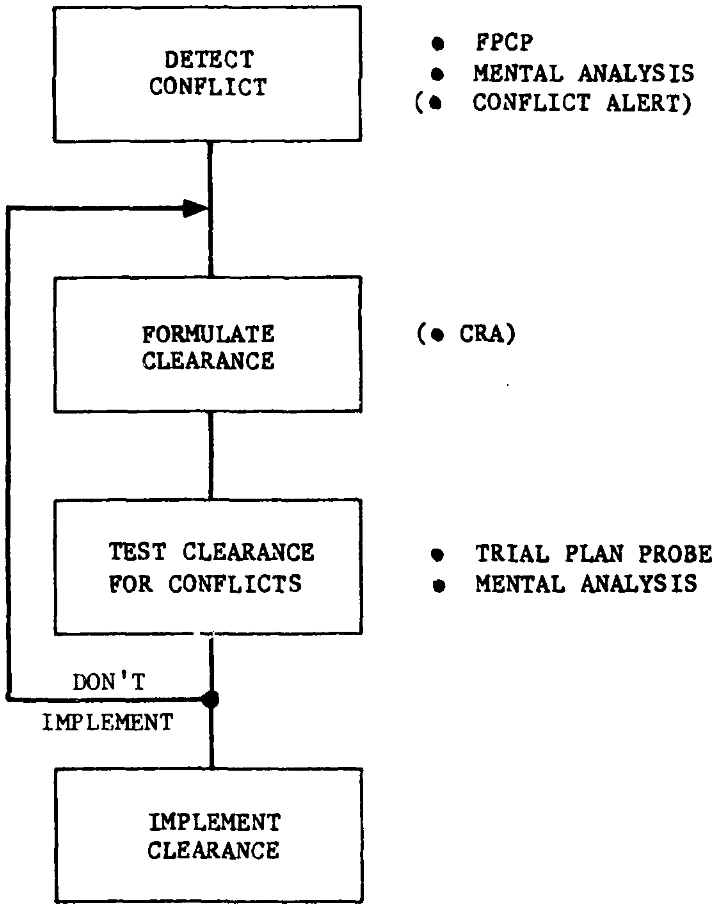


FIGURE 4-1
TASK SEQUENCE FOR DETECTION AND RESOLUTION OF AIRCRAFT CONFLICTS

4.3.2 Airspace Probe

4.3.2.1 Description

The Airspace Probe aids the controller in detecting conflicts between aircraft and particular types of special use airspace and terrain. The controller's responsibility in the AAS with respect to special use airspace will be unchanged from NAS Stage A. It is the controller's responsibility to clear non-participating aircraft via routing which will provide approved separation from the special use airspace, unless clearance of non-participating aircraft in or through the area is provided for in a Memorandum or Letter of Agreement. If such clearance is provided for, the flight may be cleared through the area if approved separation may be applied between the non-participating aircraft and other aircraft or activity in the area. (Sec. 2, "Special Use and ATC Assigned Airspace," Handbook 7110.65C [8])

It is the pilot's responsibility, today and in the future, to be aware of areas of special use airspace and, unless permission to enter an area has been granted by the using agency of the area, to structure his flight plan such that these areas are avoided. Most special use airspace is either identified on the pilot's aeronautical charts or is specified in NOTAMs. (The pilot's responsibilities are unaffected by the controller's use of the Airspace Probe.)

The Airspace Probe will be a strategic tool since it is to be used to detect airspace conflicts in which the predicted violation is a "long" time in the future. The E-MSAW function currently being implemented in NAS provides a tactical counterpart to the probe by detecting short-term violations of special use airspace and terrain areas, using radar track data.

Since the Airspace Probe is expected to examine the entire path of an aircraft through the Planning Region, some airspace conflicts may be detected considerably in advance of the predicted violation (similar to Advisory Conflicts). This advance notice of possible airspace conflicts has two implications:

- Very early coordination with the pilot may be effected, to allow the pilot to resolve the problem (since he has primary responsibility for avoiding special use airspace).

- Resolution of the problem may be deferred (because of controller workload) until the aircraft is within

proximity of the sector in which the airspace conflict occurs.

These activities would involve two different uses of the Airspace Probe information--each with its own division of responsibilities between the pilot and controller. Associated with these two uses are two types of messages sent to the controllers: an Airspace Violation advisory message and an Airspace Violation alert message. The determination of the type of message to be sent can be based upon the time to go to the point of violation. The proposed operational use of each of these messages is described below.

4.3.2.2 Airspace Violation Advisory Message

If an airspace conflict is detected more than a stated (system parameter) number of minutes before the predicted violation, an Airspace Violation advisory message is sent to the controller then in control of the aircraft (or about to be in control if the aircraft has not yet entered the center). The message notifies the controller of the existence of an airspace conflict further downstream in order to inform the pilot that a new plan or authorization to enter the area is required. The pilot thus has an early opportunity to modify the plan himself, rather than have a controller provide a resolution at a later time.

The controller's responsibility with respect to an Airspace Violation advisory message will probably be to treat the pilot notification as an additional service. If time and workload conditions permitted, the controller will do the following (Figure 4-2):

- Advise the pilot of the problem
- Approve/disapprove the pilot-suggested plan amendment (if the pilot offered an amendment)
- If assistance is requested by the pilot, suggest a plan amendment which resolves the problem

If workload conditions permit the controller to respond to the advisory message, he should, after notifying the pilot, acknowledge to the system that the pilot has been notified. Acknowledgment of the message would indicate to the system that no more advisory messages would need be given to subsequent controllers. If, on the other hand, the controller receiving the message were unable to respond to it because of the workload, and the aircraft were handed off to the next sector, the controller for

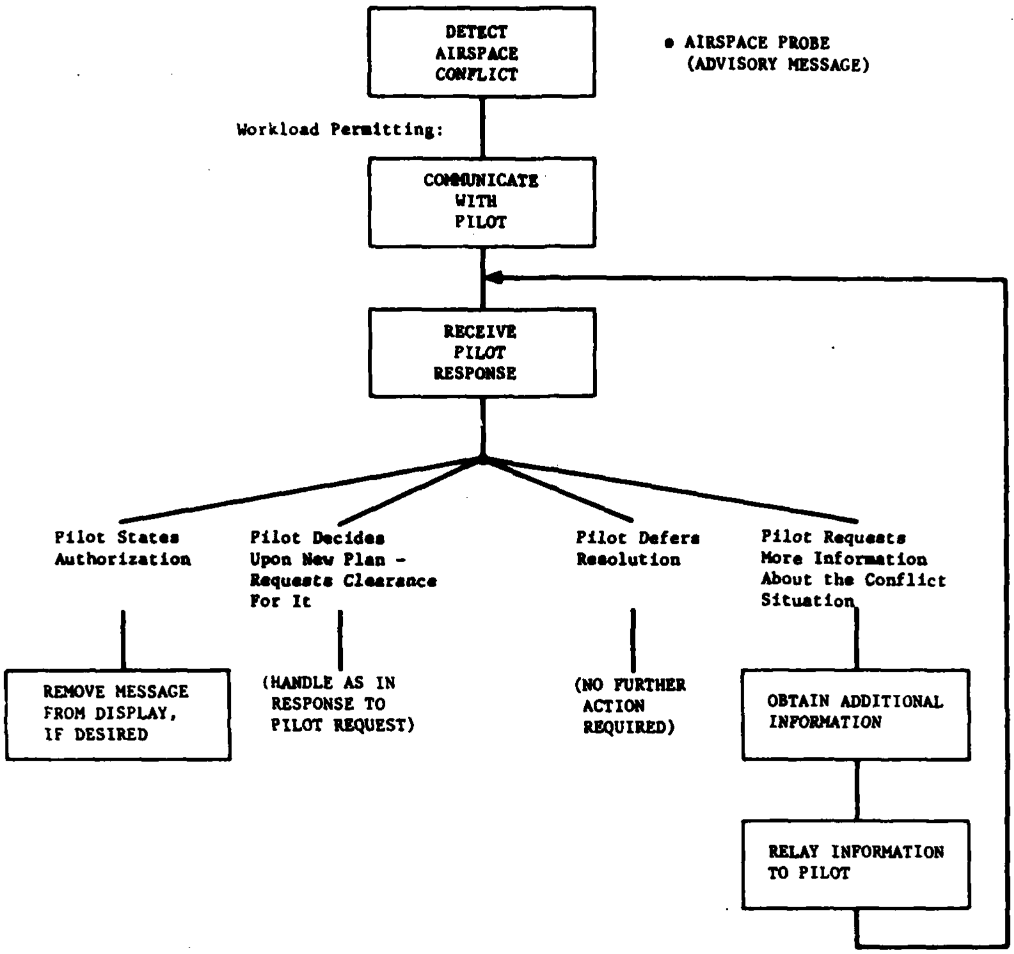


FIGURE 4-2
TASK SEQUENCE FOR DETECTION AND RESOLUTION OF LONG-RANGE AIRSPACE CONFLICTS

that sector would also receive an Airspace Violation advisory message. This would continue until either a controller acknowledged the message or the conflict was close enough in time that an Airspace Violation Alert Message would be sent.

4.3.2.3 Airspace Violation Alert Message

The purpose of this message is to inform the controller that an aircraft which is currently under his control (or will be shortly) has a conflict with an area of special use airspace or with terrain. The message will be sent to the involved controller.

The responsibility of the controller, after receipt of this message, will be to determine if the aircraft should be permitted to enter the specified airspace, and if permission is not to be given, to provide the pilot with routing around the airspace (Figure 4-3).

In both the advisory and alert messages, the controller will be presented with the information required to identify the conflict and formulate a resolution. This will include such data as: aircraft ID, identification of the violated airspace, predicted time of the violation, and identification of the sector in which the conflict would occur. Additional information regarding the conflict may be available to the controller upon request, including possible graphic display of the conflict situation.

4.3.3 Trial Plan Probe

The Trial Plan Probe is intended to assist the controller in evaluating a trial plan (i.e., one being considered for implementation) in terms of whether it would resolve any previously identified conflicts and/or create new conflicts. The Trial Plan Probe thus identifies potential conflicts between the subject aircraft and other controlled aircraft currently in or about to enter the ACF Planning Region, or special use airspace within the Planning Region. A "potential conflict" is a conflict involving the trial plan of the subject aircraft with the current trajectories of other aircraft or with special use airspace.

The Trial Plan Probe is to be an aid to the controller in long-term strategic planning, as distinct from short-term tactical control, in that it is designed to be used in situations that do not require immediate controller intervention to avoid a separation violation. An example of a typical situation in which use of the Trial Plan Probe would be recommended is in responding to a pilot request for an off-airway route segment or other change

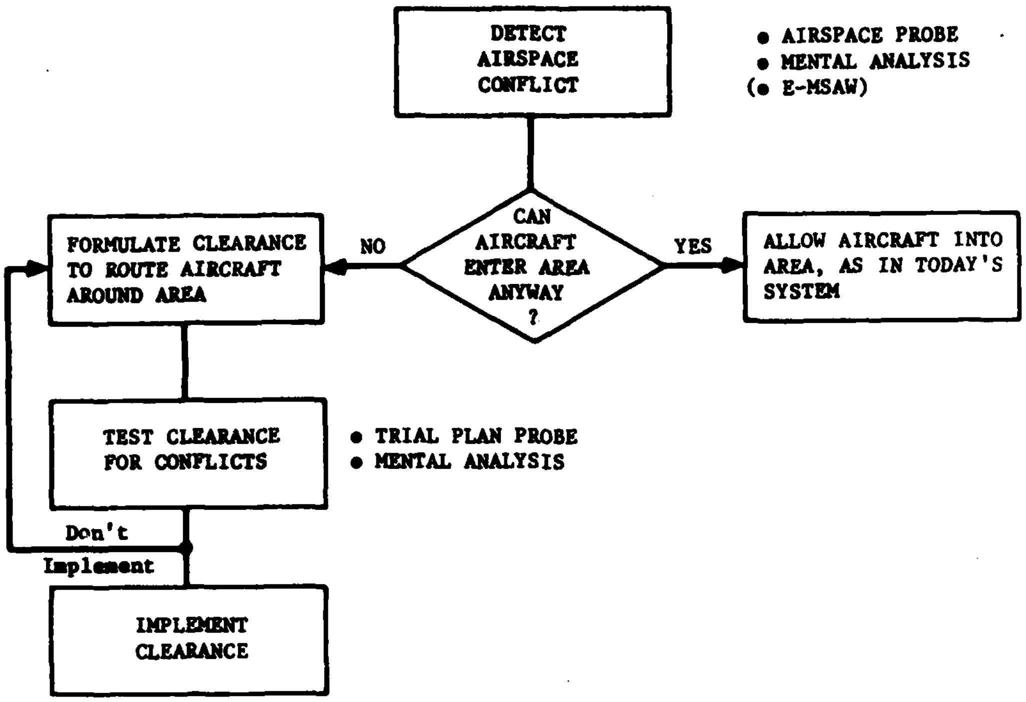


FIGURE 4-3
TASK SEQUENCE FOR DETECTION AND RESOLUTION OF SHORT-RANGE AIRSPACE CONFLICTS

in aircraft routing. In situations such as this, the controller has time to use an automated tool before issuing a new clearance. Figure 4-4 shows the controller's interactions with the Trial Plan Probe in evaluating a proposed flight plan amendment.

The Trial Plan Probe will be performed only on controller request. Trial plans will most likely be input into the computer in the same manner that current plans will be input by the controller. One way would be via the interactive display that is one of the components of the Sector Suite. When the controller had finished amending the plan and had verified that it was entered in the computer as intended, the probe would run automatically without further controller intervention. The results of the probe will be presented only to the controller who initiated the probe.

If a potential conflict is detected by the probe, the controller will be presented with a message which contains information necessary to identify the potential conflict, such as identification(s) of the aircraft involved, name of special use airspace involved, and time-to-go to violation. The information contained in this message should be the same as the information presented to the controller when a real conflict is detected by the automated probes. The displays of potential and real conflicts, however, should not be co-located, to avoid confusion. The results of the Trial Plan Probe may, for instance, be located on the Message Composition and Response Display, while the Flight Plan Conflict Probe messages may be located on the Alert and Resolution Display. If the Trial Plan Probe detects no potential conflicts, the controller will be explicitly so informed.

The controller will be expected to use the results of the probe and his knowledge of the current situation to decide whether or not to implement the trial plan. The Trial Plan Probe will not make a recommendation for or against the trial plan, but only identify potential conflicts or indicate that no potential conflicts were found. If the controller decides to implement the trial plan, the controller will transmit an appropriate clearance to the pilot and receive an acknowledgment. The controller will then indicate to the computer that the trial plan is to be accepted as the current plan. If it is determined that the trial plan is unacceptable, the controller could reject it and repeat the evaluation process with an alternative plan.

The Trial Plan Probe will give the controller the capability to test alternative clearances and resolutions before coordinating

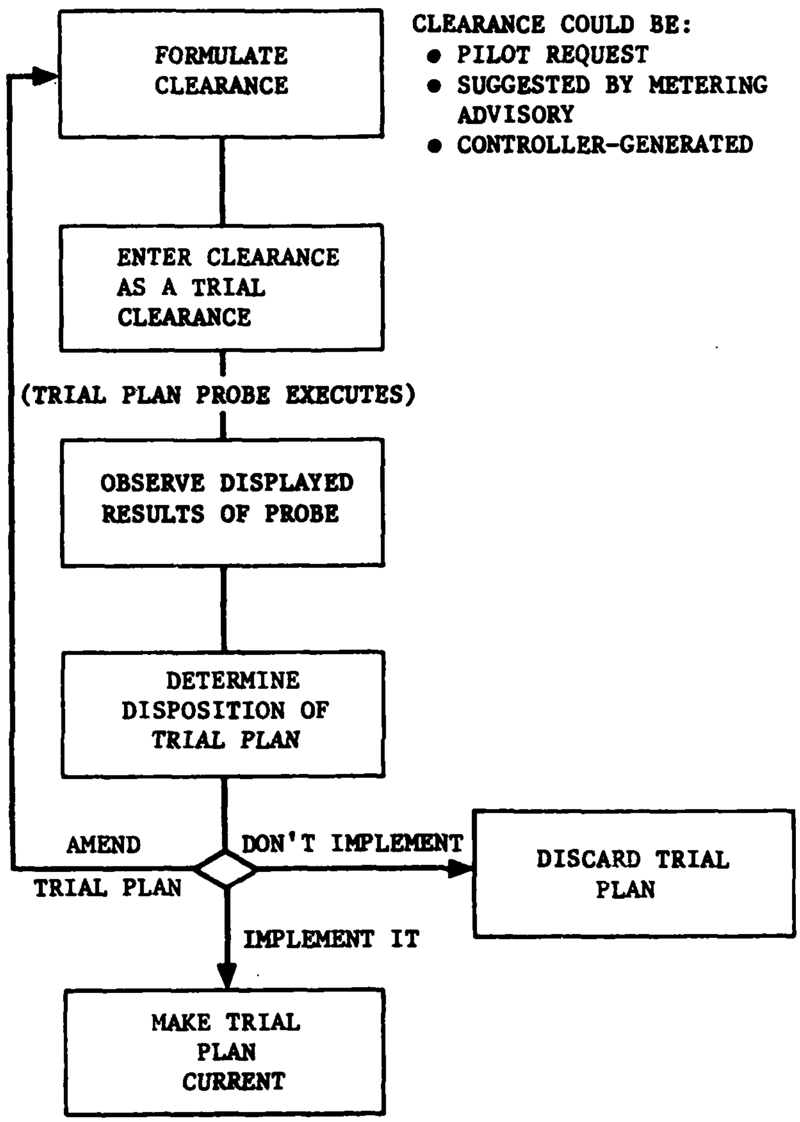


FIGURE 4-4
TASK SEQUENCE FOR TRIAL PLAN PROBE

with the pilot or other sectors. The trial plan could be altered at will by the controller, because it will not be part of the general data base until the controller makes it current. This would mean, for example, that trial plans will not be probed against by other subject aircraft.

The other probe functions, Flight Plan Conflict Probe and Airspace Probe, could also be used to test alternative clearances, by entering the trial plan as a flight plan amendment and then observing any resulting conflict messages. However, a separate Trial Plan Probe capability would offer several clear advantages.

First, the other probes would not always present the controller with enough information to make an informed decision about the trial plan. Since the automated probes would present no message to the controller if no conflicts were detected, the controller would not be able to determine whether absence of a message indicated that the probe had not yet been completed or that the probes were completed without finding any conflicts.

Secondly, use of the other probes to test an alternative would destroy the current plan in the system data base. The plan the computer knew about (and thought was real) would not be the plan the pilot knew about (and was flying). System integrity would be degraded since all detected conflicts would have to be evaluated by the controller as to whether they were based on trial plans or on current plans. In order to restore the current plan, the controller would need to remember the current clearance and enter it as a new amendment.

The integrity of the probes could be jeopardized and controller workload increased if the ability to probe trial plans were not provided; hence, a Trial Plan Probe seems to be needed.

4.3.4 Sector Workload Probe

The Sector Workload Probe is intended to aid supervisory personnel such as Area Supervisors and Area Managers in planning and conducting sectorization (combining and decombining sectors) and positional manning. The probe information which is to be displayed to the supervisor will show the current and predicted values of certain workload-related measures for each sector. The information for each sector may include data for various time periods in the future up to the limit of the probe function. Estimating that, at some later point, a sector will experience a "significant" increase or decrease in some workload-related factor, the probe will display that information for possible supervisory action.

The following data for each sector will be provided by SWP:

- The current and anticipated number of aircraft
- The current and anticipated number of conflicts, according to as yet undefined criteria
- Some "weighted" sum of anticipated planned actions related to the number of clearance changes to be issued
- The current and anticipated density of the traffic flow

Lastly, a single measure could be provided which would represent an aggregate of all the above measures. This could help to improve the supervisor's efficiency and capacity for handling the information. Detailed information (e.g., number of aircraft, number of conflicts, etc.) may be needed for some decisions, but the aggregated workload measure may be more suitable for other purposes, such as obtaining a quick overview of the workload situation.

The supervisor should be able to organize the sector workload information into time intervals (e.g., ten minutes) and into time periods (e.g., current clock time plus one hour) that can be varied as needed. The supervisor is expected to be able to initiate a request for the immediate display of that information or it may be displayed at regular intervals (e.g., in aggregated form every five minutes).

In addition, the supervisor or manager must consider other information which would be available from other sources, such as the following:

- The currently active sectors, including those combined or decombined (this is called the area pattern or area configuration)
- The current manning levels for each sector (one-person, two-person, etc.)
- Sector status data, such as navigation or communication equipment outages
- The availability of additional control personnel or backup equipment
- The time intervals for which the above items apply

It will be the responsibility of the supervisor or manager to interpret the significance of the different categories of information and determine the manner in which to use the information. By comparing the expected sector workload with the current sector workload, the supervisor can determine whether or not resectorization or manning changes are needed. Such decisions will be based upon experience and according to ATC rules and directives.

4.4 Impacts of the Advanced Automation Tools on the Controller

The new tools for the controller which are introduced in the AAS are intended to provide several significant improvements upon current ATC capabilities. Perhaps the most significant enhancement is expected to be the ability of the probes to detect conflict situations sooner than the human can, under a wide range of circumstances. The human's ability to make accurate projections of the expected flight path of an aircraft is reasonably good for short look-ahead times, but declines as look-ahead times increase.

By giving the controller more time in which to resolve the conflict, the probes are intended to improve the safety and efficiency of the ATC system. The possible resolution strategies available to the controller would increase to include those, such as speed changes, which require ample lead time for their effect to be felt. It seems reasonable to expect that the use of immediate maneuvers and workload-intensive resolutions would decline correspondingly.

It is also expected that the probes will provide the information on aircraft intents and other conflict details that can be presented to the controller in an integrated, unified format. By reducing the amount of time required to "get the picture," the probes should allow the controller more time to formulate and evaluate resolutions.

Lastly, the probe functions can help to reduce the amount of coordination between controllers in certain circumstances. For example, Trial Plan Probe could be used to eliminate those flight plan amendments which would result in a conflict <u>before</u> coordination with another sector is attempted. It may even be desirable to share the probe results with the other sector, as part of the coordination process.

The probes will impose some additional requirements on the controller in order to obtain these benefits. In addition to learning new computer entries, the controller must place

additional emphasis on such good control practices as entering all flight plan amendments promptly and maintaining a close conformance between the actual route of the aircraft and its current clearance (by updating the clearance or by guiding the aircraft back into conformance).

The probes operate on the flight plan information in the data base, and will be most accurate when the data base is up-to-date and representative of the current situation, i.e., when the aircraft and trajectory are in conformance. The computer cannot detect conflicts on flight plans it does not know about, or construct a valid trajectory for an aircraft which is out-of-conformance with its clearance. For example, an aircraft may be out of conformance because it is on radar vectors, if the vectors are not made known to Trajectory Estimation. When an aircraft is out of conformance, the controller must assume additional responsibility for monitoring that flight, and cannot rely on the Flight Plan Conflict Probe or Airspace Probe, until that aircraft returns to its computer-known flight path.

4.5 Display/Input Considerations

With the additional emphasis to be placed on maintaining the system data base, it is essential that the controller interface be designed to facilitate entry of the required information. Similarly, the mode in which information is displayed to the controller will greatly affect the usability of the advanced automation functions.

The following section presents some considerations for designing the input and output characteristics of the advanced automation functions. These are not detailed message formats or displays; such formats need to be developed through analysis and testing before implementation in the field, and are beyond the scope of this initial investigation. However, the discussion and guidelines which follow should give an indication of the scope of the input/output design task.

4.5.1 Display Formats

The first display consideration is determining the kind and amount of information necessary for controllers and supervisors to perform their particular tasks. This information has been discussed in Section 4.3, "Use of the Advanced Automation Controller Tools," for each specific function.

In addition to the information content of each display, the form of the display is important in determining its usability. For

example, Flight Plan Conflict Probe will result in alert or advisory messages to the controller which could be presented in an alphanumeric (or textual) display. To display a conflict between two aircraft, an alphanumeric display showing such quantities as the identities and flight status (e.g., altitude, ground speed, etc.) of the two aircraft, and time-to-go to violation, can be read quickly and accurately. If, however, the relative positions of the two aircraft are required to determine corrective action, then a graphic or map-type display might be appropriate. As a supplement to the text messages, a graphic or pictorial presentation may include the location of aircraft, special use airspace, and the point of violation, as well as aircraft trajectories. In addition, it could display navigation information (e.g., routes, navigation aids, etc.) and sector boundaries. The advantage of such a graphic display is that it can combine many items of information into a single integrated presentation.

In general, textual information is useful for abstract items such as flight IDs, flight status, and other quantitative data. Graphic displays can provide an integrated presentation of relational or qualitative data, such as aircraft locations and estimated trajectories, or for showing changes in values over time.

For example, the Sector Workload Probe display should show comparisons (or differences) between current sector workload and anticipated sector workload as well as provide quantitative values of the various parameters of sector workload. The format may therefore be in either alphanumeric or in graphic form (e.g., line or bar graphs). It is expected to include a variable time scale in the sense that the operator can select the increment and span of time over which sector workload data will be displayed. The result is to be a predictive display capable of representing the fluid aspects of sector workload and, of course, easy for the supervisor to interpret.

4.5.2 Display Dynamics

Display dynamics refers to the manner in which controllers and supervisors interact with the displays in real-time operations. The display dynamics will be an important topic for testing.

For example, throughout this section a distinction has been made between Priority and Advisory Conflicts and the corresponding alert and advisory messages. If multiple messages are displayed to the controller at the same time, they may need to be prioritized (on the basis of such factors as time-to-go, minimum

separation, etc.). A conflict with the highest priority could be placed at the top of the list, and the controller may then be directed to resolve the highest priority conflict first. An alternative approach would be to have the conflicts displayed in a straightforward chronological order with the controller responding on a first-come, first-served basis.

A great deal of information may be available for display to the controller. The optimum amount and type can be found only by testing. However, one would expect that as the amount of information displayed increases, there would be increasing concern about display clutter. One solution would be to provide controllers with control over the amount and type of information displayed at any time. An alternative would be to not have any of the information except the very minimum immediately available to the controller, with the display of additional information available only at controller request.

4.5.3 General Design Guidelines

The following section considers the application of good design practices to the AERA 1.01 functions. There are many references which discuss such guidelines; this section is intended to merely illustrate their possible application to AERA.

The alphanumeric display for Flight Plan Conflict Probe data, for example, should be able to alert the controller and quickly direct his attention to existing Priority and Advisory Conflicts. The display should provide some guidance for corrective action. The alert and advisory messages presented on the display may appear as a one-line message string or as an expanded message string on a Priority/Advisory Conflict list. The list may be arranged chronologically (i.e., time-to-go) and/or categorically (i.e., Priority Conflicts clearly grouped and separated from Advisory Conflicts). The messages should be concise and presented in a fixed tabular format so that the controller will always know where to look. Finally, the messages should be closely keyed to the information coding procedures and symbology in current use; any difference needs to be strongly justified and tested.

As another example, the Sector Workload Display should provide Area Supervisors and Managers with sector workload information in a form compatible with current sources of information. Further, the time element or prediction span should be adequate to allow for any "long-term" assessment of sector workload. Finally, the display should provide an interactive mode, to allow the user to select the data to be displayed in the most

useful form. It should, for example, provide for the display of detailed or summary (i.e., aggregated) information concerning sector workload as well as provide the means to manipulate the time scale of the display. The supervisor should be able to obtain aggregated or detailed information for an entire center, or a single sector or several adjacent sectors for selected periods of time, depending upon the supervisor's needs.

5. ADVANCED AUTOMATION AND AIR TRAFFIC MANAGEMENT

The previous section discussed the possible effects of the AERA 1.01 functions on the procedures and tasks of individual controllers and supervisors. In certain cases, these new automation capabilities may result in procedural or managerial changes which affect the entire controller community. For instance, the advanced automation functions could have implications on staffing levels of operational personnel or on practices of positional manning of control sectors (one-person, two-person, etc.). Of particular interest is the aggregate effect on manpower and productivity. Therefore, it is appropriate to consider the implications of the tools described in this report in regard to management issues related to these automated capabilities. Section 5 discusses these issues and evaluates the pertinent effects.

In Section 5.1, specific effects of the Flight Plan Conflict Probe and Airspace Probe on Air Traffic Management are considered. The Sector Workload Probe is considered in Section 5.2.

5.1 Flight Plan Conflict Probe and Airspace Probe

5.1.1 Staffing and Manning

Staffing, in this report, means the numbers of controllers, supervisors, and other personnel designated for an air traffic control facility. Manning means the assignment of personnel to the operational positions. This section does not discuss the FAA's policies and procedures for staffing and manning, but is concerned only with the effects of adding Flight Plan Conflict Probe, Airspace Probe, and Trial Plan Probe to the ATC system configuration prevailing at the time. The current NAS Stage A system will be the basis for discussion of ATC procedures or practices where it seems likely that these will not change significantly before the probes are added.

5.1.1.1 Controllers

As indicated in the assumed ground rules (Section 4.1, "New Control Tools"), the controller will continue to hold the ultimate responsibility for detecting and resolving conflicts using all available information, whether from the probe functions or otherwise. In other words, controllers are not to rely solely on the probes to detect conflicts unless detection requires information that the controller does not otherwise have. The controller will be directed to take appropriate action when notified of a probe-detected conflict situation.

Such actions include observing the display and taking actions, such as Trial Plan Probes and coordinations, as needed to resolve the conflict.

For these reasons, probe-related actions could add to the aggregate workload. Such additional workload, even if not alleviated by other aspects of automation, does not seem to be enough to require increases in staffing levels. At most, this workload could affect criteria for manning a sector with one or two controllers.

Factors which act to alleviate the "added workload" enough to counterbalance it, or possibly reduce the aggregate workload, would be related to more efficient planning and a more effective distribution of workload among two or more sectors. For example, one sector's planning may reduce another sector's workload while its own workload may be reduced by yet another sector's planning. Each sector would thus benefit from such a distribution of control functions.

The overall effect of these conditions on total sector workload cannot be determined until operational details are made clearer and operational testing can be performed.

5.1.1.2 Supervisors

Area Supervisors will be responsible for overseeing the performance of controllers under their supervision while performing probe-related tasks. This includes overseeing during live operations, training and upgrading, performance evaluations, and similar duties.

With respect to the effects of possible increases in workload discussed just above, supervisors may apply changed criteria in implementing one-person or two-person sector manning. These criteria may involve requirements for coordination actions or frequency of use of the Trial Plan Probe. The frequency of use of the Trial Plan Probe will depend upon the frequency of responses to pilot requests for flight plan amendments or the use of the probe in conflict resolution.

5.1.2 Personnel Policies

5.1.2.1 Training and Proficiency Levels

The new actions called for by the probes will require additions to documentation for initial training and proficiency maintenance training. These actions include those associated with manual

inputs, the memorization and use of new terminology and concepts, and new phraseology for operations. In addition, new training will include all aspects related to new Directives. Finally, additions to on-the-job training will be required.

The impact of the AERA 1.01 functions on training will be in addition to, and should be integrated with, the changes resulting from the introduction of the AAS and the Sector Suite.

Proficiency levels in the performance of certain probe-related actions may be required to meet fairly rigid standards for uniformity and promptness of action in order to provide a data base that will ensure the validity and timeliness of conflict detection by probes. It is possible that effective and efficient use of the Trial Plan Probe will require higher levels of proficiency in awareness of sector and related airspace details than are typical in the present NAS system.

5.1.2.2 Position Qualification

The discussion in 5.1.2.1 described new topics to be included in position qualification. There seem to be no grounds for suspecting that the addition of probe-related duties to control and supervisory operations will significantly increase the difficulties of qualifying for positional certification.

5.1.2.3 Proficiency Evaluation

The major effects on proficiency evaluation of the additions of Flight Plan Conflict Probe and Airspace Probe to positional duties of controllers and supervisors are related to the additional actions and the possibly higher proficiency levels, and to the need for uniformity of task execution and promptness of action as discussed above. These matters are discussed further in Section 5.1.3.5.

5.1.2.4 Career Structures

No significant impact on career structures or career progression for controllers and supervisors is anticipated with the addition of the probe functions.

5.1.3 Changes to Directives

5.1.3.1 Categories of Directives

There are four mutually exclusive and exhaustive categories of Directives for controllers and supervisors; these are called

Mandatory, Preferred, Permitted, and Prohibited. Directives related to probes may fall in any of the four categories.

- Mandatory means required with no freedom of choice. The word "shall" or a statement in the imperative sense indicates that a Directive is in the Mandatory category.

- Preferred means first choice among a set of specific alternatives. Preferred choices must be made unless conditions demand otherwise. The term "should" indicates that a Directive is in the Preferred category.

- Permitted means that a choice can be made from a set of specified alternatives without regard to enforced preference. Permitted indicates when a choice can be made based on experience and judgment. The word "may" indicates that a Directive is in the Permitted category.

- Prohibited is the "negative Mandatory," meaning that the action indicated is to be categorically avoided. The terms "shall not" or a statement in the negative imperative sense indicates that a Directive is in the Prohibited category.

5.1.3.2 Demand for New Directives

The simultaneous incorporation of new information on the displays, new tools, new procedures, or new actions will present a need for appropriate Directives. The principle at work here is that the controller and supervisor must be able to refer to documented materials in choosing and executing authorized control actions. In the full sense of the term, a controller's or supervisor's roles and responsibilities are defined by Directives. The reasons are that Directives are inherent in training, qualification, certification, operational requirements, and legal liabilities for all personnel in the ATC system. All such Directives related to the Flight Plan Conflict Probe, Airspace Probe, and Trial Plan Probe will depend upon the ground rules for related operations. Therefore, attempting to specify the probe-related Directives at this time would be premature.

5.1.3.3 ATC Handbook 7110.65

For controllers, the probe-related Directives would be expected to undergo development as a routine change in ATC Handbook 7110.65 [8] and related documents. The policies, procedures, and related processes in revising the Handbook are not discussed here.

5.1.3.4 Supervisors' Handbook

It is expected that a supervisor's handbook similar in application to the Controller's Handbook will be in use by the time the probes become operational. Thus, what has just been said about the controllers' Handbook would apply to the supervisors' handbook as well.

5.1.3.5 Work Practices and Techniques

The probes may present new requirements for uniformity in the work habits and techniques among controllers. Trajectory Estimation can work only with the data available to it. Delays and inconsistencies in the timing and sequencing of manual inputs to the computer could affect the validity of the data on which the probes are calculated. That is, clearances delivered but not yet entered into the computer, or entries made before clearances are delivered, could create differences between actualities and the data base. A false data base would reduce the operational validity of the probe outputs, depending on how the probes process the available data.

While automated features such as ETABS might provide a significant measure of regularity and consistency of sector operation, it still holds that related activities such as coordinations, with or without Trial Plan Probes, will also need to be performed with the required uniformity. It is also possible that the required uniformity will involve higher levels of proficiency than otherwise might be the case. These effects also depend on the final ground rules and have not been analyzed at present.

It would appear that the requirement for standardized performance at higher levels of proficiency will call for an increase in the number and proportion of Directives in the Mandatory and Prohibited categories.

5.2 Sector Workload Probe

The effects of Sector Workload Probe on Air Traffic Management would apply to the positions of operation to which the information would be sent and displayed. The affected positions would be the Area Supervisor or the Area Manager or both in some degree. This is so because these are the only operational positions responsible for carrying out the policies and procedures for sectorization and positional manning of the control positions.

The actions that would be carried out at these positions in response to the information provided by Sector Workload Probe are not expected to be significantly different from existing actions affecting sectorization and positional manning. Since the information from the probe may be more complete, more timely, and available earlier than would be the case without the probe, the information would affect the timeliness of these actions.

Therefore, no significant effects on supervisory staffing and manning seem involved. Specific additions to materials and content relevent to training and proficiency qualifications would be required, but do not seem to imply more than learning to read the displays, coordinating as required, and making simple manual inputs in compliance with Directives.

Thus, Sector Workload Probe would require appropriate changes in the Directives for the affected positions. In addition, corresponding changes would be made in the supervisor's handbook. New terminology and phraseology would be required in voice communications for the associated coordinations and reference to the displays. The responses to Sector Workload Probe with respect to changes in sectorization would also be an item for recording in the daily operations log. This recording could be arranged automatically as part of manual inputs and presented as displays or hard copy upon request.

Further analysis and description of the effects of Sector Workload Probe on Air Traffic Management may be initiated at a later date after its function and how it works are more clearly defined. These later descriptions would include a set of ground rules for this probe.

6. OPEN ISSUES

The preceding sections have discussed the major questions related to the AERA 1.01 functions:

- What are the characteristics of the new functions?
- How do they interface with the other ATC software functions?
- How do the new tools affect the controller's responsibilities and performance of his tasks?

There are still many unresolved issues which must be addressed in the process of implementing AERA 1, related to function performance, message display and input, testing, and other areas. Some of these issues will be outlined in the following sections. The purpose of this discussion is not to present a complete discussion of all the issues, but rather to indicate the general areas where more research will be required.

6.1 System Design Issues

This document has described how the AERA 1.01 functions may be implemented and used under routine control circumstances. For the most part, the functions have been described in use for en route traffic within a single sector or a single ACF. The complete design of AERA in the AAS will need to consider non-routine circumstances as well.

For example, the AERA design will need to deal with transactions between facilities, both other AERA facilities and non-AERA installations such as terminals. The AERA facility should be able to receive aircraft and messages from the non-AERA facility as in the current system, with at most minimal modifications to the procedures of the non-AERA facility. Further study is needed on sending aircraft and messages to the non-AERA facility, to ensure that AERA can accommodate the needs of the non-AERA system.

Equally important will be the interfaces and communications between AERA facilities. The AERA 1.01 functions are designed to operate within a single ACF's airspace, but there will be an operational advantage at some point in coordinating the implementation of the functions across ACF boundaries. For example, resolving aircraft conflicts near the ACF boundary may require knowledge about traffic in the next ACF; either this traffic data could be made available to the first center, or the second ACF could use the data from the first ACF to generate a

conflict resolution that would then be sent to the first center for implementation.

Some of these boundary issues can be treated in AERA 1.01 by the specification of "Planning Regions" which extend beyond the center's airspace and therefore overlap. If AERA knows about all traffic within the center's Planning Region, then the center boundaries will be theoretically transparent to the planning functions. The extent of the Planning Region must be analyzed; if it extends too far into the other center's airspace, too much of the AAS's capacity may be devoted to monitoring the other center's traffic; if it does not extend far enough, the planning functions may lose effectiveness in the vicinity of the boundary.

Provisions will also need to be made in the design of AERA 1.01 for those cases in which the automation is degraded. For example, the AAS Specification [3] calls for progressive shedding of functions if the AAS is overloaded or partially incapacitated; the controller would need to be informed if the Flight Plan Conflict Probe or Airspace Probe functions were no longer available.

In this area as in others, such as functional performance and relationship to other ATC functions, care must be taken in the design of the AERA 1.01 functions to ensure that they are not inconsistent with the rest of the AAS Specification.

6.2 Functional Performance Issues

The issues related to the performance of the AERA functions may be divided into three broad categories:

- What the function should do.
- How well the function should do it.
- What data or outside functions are therefore required.

The advanced automation functions process data on aircraft performance, wind and temperature, and aircraft intentions (i.e., the flight plan). This information must come from external sources. The performance of the functions will depend upon the type and accuracy of the data available to the functions, as well as the characteristics of the processing algorithms. Additional flight plan data that is not part of the present input data when an IFR flight plan is filed must be identified. This includes the accuracy requirements for both the present and the additional flight plan data.

The false and missed alarm rates of the probe functions must be realistically estimated considering the accuracy limits of all the input data, including the limits placed on flight plan data above. The acceptable values for these false and missed alarms must be determined.

The complete specification of the capabilities of each function will not be achieved until additional testing can be performed. In this way, a fuller understanding can be achieved of the ways in which the function will be applied, and the operational situations which it will need to accommodate.

For example, Flight Plan Conflict Probe relies on trajectories which are based on the aircraft's currently cleared route. If the aircraft deviates from conformance with its clearance, the trajectory is no longer an accurate estimate of future location. Testing will probably be required to determine the preferred response of AERA to an out-of-conformance aircraft: drop the aircraft from consideration, since the trajectory is no longer accurate, or process it normally but with an indication that it is out-of-conformance, on the basis that even the inaccurate trajectory is still the best available estimate of the aircraft's intentions. As previously mentioned, in such a situation the controller would be urged to reestablish conformance between the aircraft and its trajectory as quickly as possible, either by returning the aircraft to its cleared route or by amending the flight plan data base.

One possible cause of an out-of-conformance condition might be that the aircraft was being vectored off the published airway, for any of several possible reasons: conflict resolution or metering, for example. To be most useful, the AERA functions should apply equally well to all controlled aircraft executing routine maneuvers, including vectors. This will probably lead to a requirement for a controller capability to specify each vector to the automation so that it could be incorporated into the trajectory; this would help to reduce the occurrence of out-of-conformance situations. Accommodating pilot-initiated deviations to avoid severe weather will be another, perhaps more difficult, challenge.

Other special situations where the AERA functions may be limited in their applicability could also be identified through operational testing.

6.3 Operational Issues

Decisions about the characteristics of the advanced automation functions cannot be made in a vacuum; they must consider the operational context in which the functions will be placed. The equipment available to the controller and the type of traffic to be controlled have an impact on the manner in which the controller uses the automation functions and the effect they have on control technique. Such operational issues include items of controller responsibility, workload, training, and interaction with the new functions.

For example, the new probe functions are expected to be capable of detecting possible violations of separation standards earlier than the present ATC system and human controller typically can, which presents some questions about the operational use of this information.

It was stated in Section 4 that the controller in whose sector the conflict would occur may have the primary responsibility for resolving it. Given the long look-ahead time of FPCP and AP, the aircraft involved may not be in the sector when the message is received. Any attempts to resolve the situation immediately may involve coordination between as many as three different controllers. The number of controllers involved could increase further if the controller in whose sector the aircraft is flying does not have track control of that aircraft, as in a point-out, or does not have radio communications with the aircraft. Such circumstances are probably rare, but must be considered in determining which controllers receive the advisory message concerning an Advisory Conflict, and which controller has the resolution responsibility for a conflict.

The format of the advisory and alert messages, and the formats of all output messages from the computer and all input messages to the computer, are prime candidates for further investigation. The introduction of the Sector Suite and the AAS presents an opportunity for a complete redesign of the communications between the controller and the computer, in accordance with principles of good design, to make the input/output more convenient, more usable, and more efficient.

The introduction of the new functions and new equipment needs to be planned carefully in order to disrupt operations as little as possible. Training must be carried out prior to implementation so that the controllers are familiar with the use of the new functions. Perhaps most importantly, the training should include thorough coverage of the capabilities and limitations of

the new functions, so that they may be effectively utilized by the controllers. For example, the introductory training would need to stress the need to keep the aircraft trajectories up-to-date, for the best possible performance of the conflict probe functions, as well as the continuing need for the controller to monitor for conflicts which the probes did not detect (e.g., those involving VFR or out-of-conformance aircraft).

If the controller must continue to monitor for conflicts, despite the availability of the probe functions, and if the conflict probes require additional inputs from the controller to keep the trajectories accurate, do the probes really benefit the controller? Or is there a net increase in the controller's workload without a commensurate improvement in service? It is certainly the goal of the automation effort for the benefits to outweigh the costs, and for any additional workload necessitated by the automation functions in one area to be offset, or be more than offset, by other improvements such as easier inputs or more efficient information processing. However, the actual effect of the automation functions on controller workload will not be known until testing and additional analysis are performed.

In addition to the operational effects on controllers, there may be certain operational aspects of the advanced automation functions which affect the users of the air traffic control system. If the accuracy requirements of Trajectory Estimation necessitate additional input data for each aircraft (such as takeoff weight, or planned climb/descent schedules), the details of how such information could be provided would have to be worked out with the users. Similarly, if AERA imposes any requirements on the availability or performance of any onboard equipment, such as transponders or navigation equipment, these requirements will need to be discussed with the users.

As the development of AERA proceeds, certain operational issues will be resolved while other new issues will arise. Continuing coordination between the parties involved will help to produce a final design which is well-suited for its intended purpose.

APPENDIX A

CONTROLLER TASK DESCRIPTIONS

The following tasks were chosen to illustrate how the AERA 1.01 tools will be integrated into the controller's activities.

- Detect/Resolve Aircraft Conflicts (Flight Plan Conflict Probe, Trial Plan Probe)
- Detect/Resolve Airspace Conflicts (Airspace Probe, Trial Plan Probe)
- Respond to Pilot Request (Trial Plan Probe)
- Implement Metering Advisory (Trial Plan Probe)

The tasks are ones that are currently performed and will continue to be performed when the AAS is implemented. The task descriptions include mention of NAS tools that will be available in the AAS environment, NAS enhancements that will be available, and the AERA 1.01 tools. The purpose of this section is to identify where the AERA 1.01 tools apply in the sequence of activities required to perform a specific task.

A.1 DETECT/RESOLVE AIRCRAFT CONFLICTS

These procedures are followed by the controller in whose sector a violation has been predicted to occur. The following discussion applies to Priority Conflicts, as defined in Section 4.3.

1. Detect current or future violations of separation minima by using one or more of the following methods.

NOTE: Controller is responsible for detection of conflicts, regardless of whether computer detects the conflict.

- Flight Plan Conflict Probe output on Alert and Resolution Display, which will warn of conflicts predicted by the computer based on best data available to it (flight plan, weather, a/c flight characteristics, etc.)
- non-automated techniques (same as current NAS)--visual scanning of radar tracks, interpretation and integration of flight plan data

- other automated warnings:

  - Conflict Alert
  - IFR-VFR Conflict Alert

2. Ascertain details of violation, such as:

   - aircraft involved
   - ID of sector currently in control of aircraft involved
   - sector in which violation occurs
   - location within sector
   - time of violation
   - severity (may be based on time-to-go to violation)

   Obtain these details from Flight Plan Conflict Probe message and mental analysis of flight plan data, situation display.

3. Ascertain details of surroundings of conflict that may affect resolution approach, such as:

   - intent of aircraft
   - other aircraft in vicinity
   - special use airspace
   - procedural restrictions
   - weather cells
   - minimum altitudes

   Obtain details from situation display, flight plans, knowledge of the sector.

4. Develop a resolution approach.

   - determine which separation service should be provided (lateral, longitudinal, vertical)

   - formulate trial clearance:

     - amendment to flight plan (altitude, route, speed)
     - radar vector
     - interim altitude

Clearance is based on separation service to be provided and on controller judgment as to how to provide the service. If conflict was detected by Conflict Alert, clearance can also be based on suggestion from Conflict Resolution Advisory.

5. Coordinate with other controllers, if necessary.

6. Enter the clearance into the computer. This clearance may subsequently be used as input to Trial Plan Probe or as a direct amendment to a flight plan. If the clearance is not to be used as input to Trial Plan Probe, the primary purpose of entering it into the computer at this point is as a memory jogger in case the controller is interrupted.

7. Probe trial plan (current flight plan as it would be amended by the trial clearance) for potential conflicts with other aircraft or special use airspace. Determine whether trial plan will resolve identified conflict while not creating any new conflicts.

   Use one or both of the following procedures:

   - Trial Plan Probe:

     - activate probe
     - evaluate results of probe

   - mental probe by controller (as done in current NAS)

8. Decide whether to implement trial plan:

   - controller judgment based on results of probe.

9. Implement decision:

   - if the trial plan is to be implemented:
     - transmit clearance to pilot
     - receive acknowledgment
     - indicate to the computer that the trial plan is to be implemented

   - if the trial plan is not to be implemented:

     - reject clearance
     - formulate another clearance, and repeat process

A.2 DETECT/RESOLVE AIRSPACE CONFLICTS

There are two types of situations involving airspace conflicts for which the controller receives a message from Airspace Probe. In one type of situation, the conflict involves a violation that is predicted to occur beyond the

sector in which the aircraft is currently flying or is about to enter. In the other type of situation, the violation is predicted to occur within the current sector. Since the controller's actions and responsibilities differ in the two types of situations, they are discussed separately below.

A.2.1 "Long-Range" Violations

NOTE: Resolution of "long-range" violations are to be handled as an additional service.

1. Detect predicted violation of special use airspace:

   - observe airspace violation advisory message on display.

2. Ascertain details of the violation:

   - aircraft ID
   - identification of violated airspace
   - predicted time of violation
   - identification of sector in which conflict occurs (for possible coordination)

   Obtain these details from Airspace Advisory message.

3. Communicate with pilot--describe the violation (using information from the display) so that pilot can decide upon a change to his filed plan.

4. Receive pilot response.

5. Take appropriate action.

   - if pilot states that he has authority from the using agency to enter the area:

     - delete advisory message (when an advisory message is deleted, no further advisories will be sent to subsequent controllers)

   - if resolution is to be deferred until a later time:

     - suppress advisory message (advisory message will be redisplayed to the next controller to have control of the aircraft)

- if pilot decides upon a new plan and requests clearance for it:

  - enter proposed plan amendment into computer

  - probe the plan for potential conflicts using Trial Plan Probe or manual probe

  - if problems are detected:

    -- notify the pilot that his request cannot be granted--give reasons why not (traffic, other violations, etc.)

    -- allow pilot to modify the plan again (or, time permitting, and if the pilot asks, offer a suggestion on how to resolve the problem)

  - if no problems are detected:

    -- issue clearance to pilot--receive acknowledgment

    -- indicate to computer that plan is to be implemented

- if pilot requests more information about the conflict:

  - request more detailed level of information regarding the violation. This <u>may</u> include such data as:

    -- a graphic display of the violation, showing the bounds of the violated area as well as the surrounding area (navaids in the vicinity, etc.)

    -- greater detail about the airspace involved, such as ceiling, altitude, times, type.

  - communicate this information to the pilot--receive response. (Repeat from step 5)

A.2.2 "Short-Range" Violations (Within Current Sector)

NOTE: Prompt resolution of violations predicted to occur within current sector is mandatory.

1. Detect current or future violations of special use airspace by using one of the following methods:

   - observation of the Alert and Resolution Display (messages alerting the controller of airspace violations and containing a brief description of the violation are posted in this area)

   - mental techniques (same as current NAS--this includes visual monitoring of radar-reported positions of aircraft, and interpretation and integration of flight plan data)

2. Ascertain details of the violation, such as:

   - aircraft ID
   - identification of violated airspace
   - predicted time of violation
   - identification of sector which currently has control of the aircraft

   Obtain these details from Airspace Probe message and mental analysis of flight plan data, Situation Display.

3. Determine if aircraft is allowed to enter the special use area.

   - participating aircraft (authorized by using agency)

     - communicate with the pilot--notify him of violation and inquire as to his authorization--receive response

     - alternatively, check list of authorized aircraft if available (from using agency)--if aircraft is on the list, verify with pilot

   - LOA or prior coordination exists allowing non-participating aircraft to enter area

     - controller must insure separation from other aircraft passing through area and from other activity within area

4. Permit aircraft that are allowed to enter special use airspace to do so.

   - if aircraft is a participating aircraft

- delete violation notification message

- if aircraft is a non-participating aircraft

  - if necessary, formulate a clearance taking aircraft through the area

  - if clearance is different from current clearance (because of maneuvers to avoid other traffic in the area, for instance), notify pilot and advise him of activity in the area--receive acknowledgment

  - monitor progress of aircraft through the area to maintain separation

  - delete violation notification message, if desired

5. Alter clearances of aircraft that are not allowed to enter the special use airspace so that they will avoid the area.

   - inquire as to pilot's intentions

   - formulate a clearance which will allow the aircraft to avoid the area. This clearance could be a:

     - change in altitude
     - change in route
     - change in speed (not usually applicable)
     - rad vector

   - enter trial clearance into computer, including radar vectors to the extent they are specifiable. Trial plan is current plan as it would be amended by the trial clearance.

   - probe trial plan for potential conflicts. Use one of the following procedures:

     - Trial Plan Probe:

       -- activate probe
       -- evaluate results

     - mental probe (as done in current NAS)

   - decide whether to implement trial plan

- controller judgment based on results of probe

- if trial plan is to be implemented:
  - transmit clearance to pilot
  - receive acknowledgment
  - indicate to computer that the trial plan is to be implemented

- if trial plan is not to be implemented:
  - reject clearance
  - try another clearance

A.3 RESPOND TO PILOT REQUEST

1. Receive request from pilot.

   Request may be for:

   - amended route
   - new altitude (e.g., because of turbulence)
   - new speed
   - assistance, such as:
     - to avoid weather
     - to return to cleared route
   - air file (flight plan initiation)

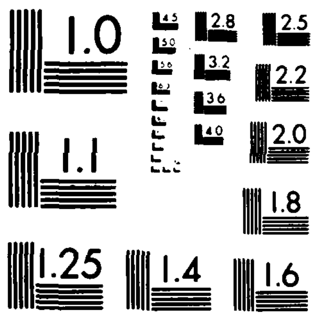
2. Acknowledge and note receipt of request.

3. If necessary, formulate a specific clearance based on request. (Pilot may have requested a climb to escape turbulence, but did not request a specific altitude. Or pilot may have requested help in avoiding a weather cell, for example.)

   Controller should base clearance on such items as:

   - desired goal
   - environmental conditions (weather, winds, turbulence, etc.)
   - altitude restrictions (Minimum Vectoring Altitude, Minimum En Route Altitude, etc.)
   - known special use airspaces
   - flight plans of known aircraft in vicinity
   - ATC rules (direction of flight, etc.)

AD-A136 831 OPERATIONAL AND FUNCTIONAL DESCRIPTION OF AERA 101(U) 2/2
FEDERAL AVIATION ADMINISTRATION WASHINGTON DC SYSTEMS
ENGINEERING SERVICE W U SWEDISH ET AL. 31 SEP 83
UNCLASSIFIED DOT/FAA/ES-83/9 F/G 17/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

- aircraft capabilities
- relevant radar data
- uncontrolled tracks in area

4. Coordinate with other controllers, if necessary.

5. Enter trial clearance into computer. This clearance may be used as input to Trial Plan Probe or as a direct amendment to the flight plan. If the clearance is not to be used as input to Trial Plan Probe, the primary purpose of entering it into the computer at this point is as a memory jogger in case the controller is interrupted.

6. Probe trial plan (current flight plan as it would be amended by the trial clearance) for potential conflicts with other aircraft or airspace.

   Use one of the following procedures:

   - Trial Plan Probe:
     - activate probe
     - evaluate results
   - mental probe (as done in current NAS)

7. Determine whether or not the trial plan should be implemented based on results of probe. Use controller judgment.

8. Implement decision:

   - if trial plan is to be implemented:
     - transmit clearance to pilot
     - receive acknowledgment
     - indicate to computer that trial plan is to be implemented
   - if trial plan is not to be implemented:
     - inform pilot
     - cancel trial clearance
     - may try alternative clearance (pilot- or controller-generated)

A.4 IMPLEMENT METERING ADVISORY

1. Receive a metering advisory (from ERM II) which indicates such information as:

   - which aircraft must be delayed for metering
   - amount of delay to be absorbed
   - suggested maneuver to absorb delay.

2. Enter trial clearance (maneuver suggested by advisory, or other) into computer. Trial plan is the current plan as it would be amended by the trial clearance.

3. Probe trial plan for potential conflicts. Use one of the following procedures:

   - Trial Plan Probe:

     - activate probe
     - evaluate results

   - mental probe (as done in current NAS)

4. Determine whether or not the trial plan should be implemented based on results of probe. Use controller judgment.

5. If clearance is to be issued:

   - transmit clearance to pilot
   - receive acknowledgment
   - indicate to computer that the trial plan is to be implemented

6. If trial plan is not to be implemented:

   - formulate new clearance (with no automated metering aid)
   - probe for potential conflicts, as above

APPENDIX B

REFERENCES

1. U.S. Department of Transportation, Federal Aviation Administration, "National Airspace System Plan: Facilities, Equipment and Associated Development," (revised) April 1983.

2. W. J. Swedish "Evolution of Advanced ATC Automation Functions," WP-83W149, The MITRE Corporation, McLean, Virginia, March 1983.

3. U.S. Department of Transportation, Federal Aviation Adminstration, "Advanced Automation System: System Level Specification--Design Competition Phase," FAA-ER-130-005D, April, 1983.

4. J. A. Kingsbury et al., "Automated En Route Air Traffic Control Algorithmic Specifications--Trajectory Estimation," MTR-83W152, Vol. 1, The MITRE Corporation, McLean, Virginia, September 1983.

5. W. P. Niedringhaus et al., "Automated En Route Air Traffic Control Algorithmic Specifications--Flight Plan Conflict Probe," MTR-83W152 Vol. 3, The MITRE Corporation, McLean, Virginia, September 1983.

6. J. A. Kingsbury et al., "Automated En Route Air Traffic Control Algorithmic Specifications--Airspace Probe," MTR-83W152 Vol. 2, The MITRE Corporation, McLean, Virginia, September 1983.

7. W. P. Niedringhaus and A. H. Gisch, "Automated En Route Air Traffic Control Algorithmic Specifications--Sector Workload Probe," MTR-83W152 Vol. 4, The MITRE Corporation, McLean, Virginia, September 1983.

8. U.S. Department of Transportation, Federal Aviation Administration, "Air Traffic Control," Handbook 7110.65C, Chg. 5, 18 May 1983.